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# HERTZIAN WAVE WIRELESS TELEGRAPHY. II.

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WE have next to consider the appliances for creating the necessary charging electromotive force, and for storing and releasing this charge at pleasure, so as to generate the required electrical oscillations in the aerial.

It is essential that this generator should be able to create not only large potential difference, but also a certain minimum electric current. Accordingly, we are limited at the present moment to one of two appliances, viz., the induction coil or the alternating current transformer.

It will not be necessary to enter into an explanation of the action of the induction coil. The coil generally employed for wireless telegraphy is technically known as a ten-inch coil, *i. e.*, a coil which is capable of giving a ten-inch spark between pointed conductors in air at ordinary pressure. The construction of a large coil of this description is a matter requiring great technical skill, and is not to be attempted without considerable previous experience in the manufacture of smaller coils. The secondary circuit of a ten-inch coil is formed of double silk-covered copper wire, generally speaking the gauge called No. 36, or else No. 34 S.W.G. is used, and a length of ten to seventeen miles of wire is employed on the secondary circuit, according to the gauge of wire selected. For the precautions necessary in constructing the secondary coil, practical manuals must be consulted.*

* Instruction for the manufacture of large induction coils may be obtained from a 'Treatise on the Construction of Large Induction Coils,' by A. T. Hare. (Methuen & Co., London.)

Very great care is required in the insulation of the secondary circuit of an induction coil to be used in Hertzian wave telegraphy, because the secondary circuit is then subjected to impulsive electromotive forces lasting for a short time, having a much higher electromotive force than that which the coil itself normally produces.

The primary circuit of a ten-inch coil generally consists of a length of 300 or 400 feet of thick insulated copper wire. In such a coil the secondary circuit would require about ten miles of No. 34 H.C. copper wire, making 50,000 turns round the core. It would have a resistance at ordinary temperatures of 6,600 ohms, and an inductance of 460 henrys. The primary circuit, if formed of 360 turns of No. 12 H.C. copper wire, would have a resistance of 0.36 of an ohm, and an inductance of 0.02 of a henry.

An important matter in connection with an induction coil to be used for wireless telegraphy is the resistance of the secondary circuit. The purpose for which we employ the coil is to charge a condenser of some kind. If a constant electromotive force ($V$) is applied to the terminals of a condenser having a capacity $C$, then the difference of potential ($v$) of the terminals of the condenser at any time that the contact is made is given by the expression:

$$v = V(1 - e^{-\frac{t}{RC}})$$

In the above equation, the letter $e$ stands for the number 2.71828, the base of the Napierian logarithms, and $R$ is the resistance in series with the condenser, of which the capacity is $C$, to which the electromotive force is applied. This equation can easily be deduced from first principles,* and it shows that the potential difference $v$ of the terminals of the condenser does not instantly attain a value equal to the impressed electromotive force $V$, but rises up gradually. Thus, for instance, suppose that a condenser of one microfarad is being charged through a resistance of one megohm by an impressed voltage of 100 volts, the equation shows that at the end of the first second after contact, the terminal potential difference of the condenser will be only 63 volts, at the end of the second second, 86 volts, and so on.

Since $e^{-10}$ is an exceedingly small number, it follows that in ten seconds the condenser would be practically charged with a voltage equal to 100 volts. The product $CR$ in the above equation is called the

Also see Vol. II. of 'The Alternate Current Transformer,' by J. A. Fleming, Chap. I. (The Electrician Publishing Co., 1, Salisbury Court, Fleet St., London, E. C.)

* See 'The Alternate Current Transformer,' by J. A. Fleming, Vol. I., page 184.

*time-constant* of the condenser, and we may say that the condenser is practically charged after an interval of time equal to ten times the time-constant, counting from the moment of first contact between the condenser and the source of constant voltage. The time-constant is to be reckoned as the product of the capacity ($C$) in microfarads, by the resistance of the charging circuit ($R$) in megohms. To take another illustration. Supposing we are charging a condenser having a capacity of one hundredth of a microfarad, through a resistance of ten thousand ohms. Since ten thousand ohms is equal to one hundredth of a megohm, the time-constant would be equal to one ten-thousandth of a second, and ten times this time-constant would be equal to a thousandth of a second. Hence in order to charge the above capacity through the above resistance, it is necessary that the contact between the source of voltage and the condenser should be maintained for at least one thousandth part of a second.

In discussing the methods of interrupting the circuit, we shall return to this matter, but, meanwhile, it may be said that in order to secure a small time-constant for the charging circuit, it is desirable that the secondary circuit of the induction coil should have as low a resistance as possible. This, of course, involves winding the secondary circuit with a rather thick wire. If, however, we employ a wire larger in size than No. 34, or at the most No. 32, the bulk and the cost of the induction coil began to rise very rapidly. Hence, as in all other departments of electrical construction, the details of the design are more or less a matter of compromise. Generally speaking, however, it may be said that the larger the capacity which is to be charged, the lower should be the resistance of the secondary circuit of the induction coil.

In the practical construction of induction coils for wireless telegraphy, manufacturers have departed from the stock designs. We are all familiar with the appearance of the instrument maker's induction coil; its polished mahogany base, its lacquered brass fittings, and its secondary bobbin constructed of and covered with ebonite. But such a coil, although it may look very pretty on the lecture table, is yet very unsuited to positions in which it may be used in connection with Hertzian wave telegraphy.

Three important adjuncts of the induction coil are the primary condenser, the interrupter and the primary key. The interrupter is the arrangement for intermitting the primary current. We have in some way or other to rapidly interrupt the primary current, and the torrent of sparks that then appears between the secondary terminals of the coil is due to the electromotive force set up in the secondary circuit at each break or interruption of the primary circuit. We may divide interrupters into five classes.

We have first the well known hammer interrupter which continental writers generally attribute to Neef or Wagner.* In this interrupter, the magnetization of the iron core of the coil is caused to attract a soft-iron block fixed at the top of a brass spring, and by so doing to interrupt the primary circuit between two platinum contacts. Mr. Apps, of London, added an arrangement for pressing back the spring against the back contact, and the form of hammer that is now generally employed is therefore called an Apps break.

As the ten-inch coil takes a primary current of ten amperes at sixteen volts when in operation, it requires very substantial platinum contacts to withstand the interruption of this current continuously without damage. The small platinum contacts that are generally put on these coils by instrument makers are very soon worn out in practical wireless telegraph work. If a hammer break is used at all, it is essential to make the contacts of very stout pieces of platinum, and from time to time, as they get burnt away or roughened, they must be smoothed up with a fine file. It does not require much skill to keep the hammer contacts in good order, and prevent them from sticking together and becoming damaged by the break spark.

By regulating the pressure of the spring against the back contact, by means of an adjusting screw, the rate at which the break vibrates can be regulated, but as a rule it is not possible, with a hammer break, to obtain more than about 800 interruptions per minute, or say twelve a second. The hammer break is usually operated by the magnetism of the iron core of the coil, but for some reasons it is better to separate the break from the coil altogether, and to work it by an independent electromagnet, which, however, may be excited by a current from the same battery supplying the induction coil. For coils up to the ten-inch size the hammer break can be used when very rapid interruptions are not required. It is not in general practicable to work coils larger than the ten-inch size with a platinum contact hammer break, as such a butt contact becomes overheated and sticks if more than ten amperes is passed through it. In the case of larger coils, we have to employ some form of interrupter in which mercury or a conducting liquid forms one of the contact surfaces.

The next class of interrupter is the vibrating or hand-worked mercury break, in which a platinum or steel pin is made to vibrate in and out of mercury. This movement may be effected by the attraction of an iron armature by an electromagnet, or by the varying magnetism of the core of the coil, or it may be effected more slowly by hand.

* Du Moncel states that MacGauley of Dublin independently invented the form of hammer break as now used.

See 'The Alternate Current Transformer,' Vol. II., Chap. I., J. A. Fleming.

The mercury surface must be covered with water, alcohol, paraffin or creosote oil to prevent oxidation and to extinguish the break spark. The interruption of the primary current obtained by the mercury break is more sudden than that obtained by the platinum contact in air, in consequence of the more rapid extinction of the spark; hence the sparks obtained from coils fitted with mercury interrupters are generally from twenty to thirty per cent. longer than those obtained from the same coil under the same conditions, with platinum contact interrupters. The mercury breaks will not, however, work well unless cleaned at regular intervals by emptying off the oil and rinsing well with clean water, and hence they require rather more attention than platinum interrupters. It is not generally possible to obtain so many interruptions per minute with the simple vibrating mercury interrupter as with the ordinary hammer interrupter. The mercury interrupter has, however, the advantage that the contact time during which the circuit is kept closed may be made longer than is the case with the hammer break. Also, if fresh water is allowed to flow continuously over the mercury surface, it can be kept clean, and the break will then operate for considerable periods of time without attention. The mercury interrupter may be worked by a separate electromagnet or by the magnetism of the core of the induction coil.

The third class of interrupter may be called the motor interrupter, of which a large number have been invented in recent years. In this interrupter some form of a continuously rotating electromotor is employed to make and break a mercury or other liquid contact. In one simple form, the motor shaft carries an eccentric, which simply dips a platinum point into mercury, or else a platinum horseshoe into two mercury surfaces, making in this manner an interruption of the primary circuit at one or two places. As a small motor can easily be run at twelve hundred revolutions per minute, or twenty per second, it is possible to secure easily in this manner a uniform rate of interruption of the primary current, at the rate of about twenty per second. If, however, much higher speeds are employed, then the time of contact becomes abbreviated, and the ability of the coil to charge a capacity is diminished.

Professor J. Trowbridge has described an effective form of motor break for large coils, in which the interruption is caused by withdrawing a stout platinum wire from a dilute solution of sulphuric acid, and by this means he increased the spark given by a coil provided with hammer break and condenser from fifteen inches to thirty inches, when using the liquid break and no condenser.*

* See Professor J. Trowbridge, 'On the Induction Coil,' *Phil. Mag.*, April, 1902. Vol. III., Series 6, p. 393.

A good form of motor-interrupter, due to Dr. Mackenzie Davidson, consists of a slate disc bearing pin contacts fixed on the prolonged steel axle of a motor placed in an inclined position; the disc and the lower part of the axle lie in a vessel filled one third with mercury, and two thirds with paraffin oil. The circuit is made and broken by the revolution of the disc causing the pins to enter and leave the mercury. The speed of the motor can be regulated by a small resistance, and can be adapted to the electromotive force used in the primary circuit. When the motor is running slowly, the interrupter can be used with a low electromotive force, that is to say, something between twelve and twenty volts, but with a higher speed a large electromotive force can be used without danger of overheating the primary coil, and with an electromotive force of about fifty volts, the interruptions may be so rapid that an unbroken arc of flame, resembling an alternating current arc, springs between the secondary terminals of the coil.

Mr. Tesla has devised numerous forms of rotating mercury break. In one, a star-shaped metal disc revolves in a box so that its points dip into mercury covered with oil, and make and break contact. In another form, a jet of mercury plays against a similar shaped rotating wheel. For details, the reader must consult the fuller descriptions in *The Electrical World* of New York, Vol. XXXII., p. 111, 1898; also Vol. XXXIII., p. 247; or *Science Abstracts,* Vol. II., pp. 46 and 457, 1898.

The fourth class of interrupter is called a turbine interrupter. In this appliance, a jet of mercury is forced out of a small aperture by means of a centrifugal pump, and is made to squirt against a metal plate, and interrupted intermittently by a toothed wheel made of insulating material rotated by the motor which drives the pump. The current supplying the coil passes through or along this jet of mercury, and is therefore rendered intermittent when the wheel revolves. In the case of this interrupter, the duration of the contacts, as well as the number of interruptions per second, is under control, and for this reason better results are probably obtained with it than with any other form of break.

A description of a turbine mercury break devised by M. Max Levy was given in the *Elektrotechnische Zeitschrift,* Vol. XX., p. 717, October 12, 1899 (see also *Science Abstracts,* Vol. III., p. 63, abstract No. 165) as follows:

A toothed wheel made of insulating material carries from 6 to 24 teeth, and can be made to rotate from 300 to 1,000 times per minute, the interruptions being thus regulated between 5 and 400 per second. By raising or lowering the position of the jet of mercury and that of the plate against which it strikes, the duration of the contact can be

varied, so that it is possible to regulate this period without disturbing the number of interruptions per second.

The sparks obtained from a coil worked with a turbine interrupter have more quantity than the sparks obtained with any other interrupter under similar conditions, and the coil can be worked with a far higher voltage than is possible when using the hammer break. In this manner, the appearance of the secondary sparks can be varied from the thin snappy sparks given by the hammer break to the thick flame-like arc sparks given by the electrolytic break. This break can be adapted for any voltage from twelve to two hundred and fifty volts, and the primary circuit can not be closed before the interrupter is acting. The mercury in the break is generally covered with alcohol or paraffin oil to reduce oxidation, and the appliance is nearly noiseless when in operation. The mercury has to be cleaned at intervals, if the interrupter is much used. If alcohol is used to cover the mercury, the cleaning is very simple; the break requires only to be rinsed under a water tap. When paraffin oil is used, the cleaning is generally effected with the help of a few ounces of sulphuric acid in a very few minutes. It is best, however, to clean the mercury continuously by allowing the water to flow over it.

The motor driving the centrifugal pump and the fan can be wound for any voltage, and it is best to have it so arranged that this motor works on the same battery which supplies the primary circuit of the coil, the two circuits working parallel together. A rheostat can be added to the motor circuit to regulate the speed.

The turbine break driven by an independent motor, which is kept always running, has another advantage over the hammer break in practical wireless telegraphy, viz., that a useful secondary spark can be secured with a shorter time of closure of the primary circuit, since there is no inertia to overcome as in the case of the hammer break. This latter form has only continued in use because of its simplicity and ease of management by ordinary operators.

The mercury turbine interrupter has been extensively adopted both in the German and British navies in connection with induction coils used for wireless telegraphy.

Lastly we have the electrolytic interrupters, the first of which was introduced by Dr. Wehnelt, of Charlottenburg, in the year 1899, and modified by subsequent inventors. In its original form, a glass vessel filled with dilute sulphuric acid (one of acid to five or else ten parts of water) contains two electrodes of very different sizes; one is a large lead electrode formed of a piece of sheet lead laid round the interior of the vessel, and the other is a short piece of platinum wire projecting from the end of a glass or porcelain tube. The smaller of these elec-

trodes is made the positive, and the large one the negative. If this electrolytic cell is connected in series with the primary circuit of the induction coil (the condenser being cut out) and supplied with an electromotive force from forty to eighty volts, an electrolytic action takes place which interrupts the current periodically.* An enormous number of interruptions can, by suitable adjustment, be produced per second, and the appearance of a discharge from the secondary terminals of the coil, while using the Wehnelt break, more resembles an alternate current arc than the usual disruptive spark.

At the time when the Wehnelt break was first introduced, great interest was excited in it, and the technical journals in 1899 were full of discussions as to the theory of its operation.† The general facts concerning the Wehnelt break are that the electrolyte must be dilute sulphuric acid in the proportion of one of acid to five or ten of water. The large lead plate must be the cathode or negative pole, and the anode or positive pole must be a platinum wire, about a millimeter in diameter, and projecting one or two millimeters from the pointed end of a porcelain, glass or other acid-proof insulating tube. The aperture through which the platinum wire works must be so tight that acid can not enter, yet it is desirable that the platinum wire should be capable of being projected more or less from the aperture by means of an adjusting screw. The glass vessel which contains these two electrodes should be of considerable size, holding say a quart of fluid, and it is better to include this vessel in a larger one in which water can be placed to cool the electrolyte, as the latter gets very warm when the break is used continuously. If such an electrolytic cell has a continuous electromotive force applied to it tending to force a current through the electrolyte from the platinum wire to the lead plate, we can distinguish three stages in its operation, which are determined by the electromotive force and the inductance in the circuit. First, if the electromotive force is below sixteen or twenty volts, then ordinary and silent electrolysis of the liquid proceeds, bubbles of oxygen being liberated from the platinum wire and hydrogen set free against the lead plate. If the electromotive force is raised above twenty-five volts, then if there is no inductance in the circuit, the continuous flow of current proceeds, but if the circuit of the electrolyte possesses a certain

* See Dr. Wehnelt's article in the *Elektrotechnische Zeitschrift*, January, 1899.

† See *Electrician*, Vol. XLII., 1899, pp. 721, 728, 731, 732 and 841. Communications from Mr. Campbell Swinton, Professor S. P. Thompson, Dr. Marchant, the author and others. Also page 864, same volume, for a leader on the subject. Also page 870, letters by M. Blondel and Professor E. Thomson. See also *Electrician*, Vol. XLIII., p. 5, 1899, extracts from a paper by P. Barry; *Comptes Rendus*, April, 1899. See also *The Electrical Review*, Vol. XLIV., p. 235, 1899, February 17.

minimum inductance, the character of the current flow changes, and it becomes intermittent, and the cell acts as an interrupter, the current being interrupted from 100 to 2,000 times per second, according to the electromotive force, and the inductance of the circuit. Under these conditions, the cell produces a rattling noise and a luminous glow appears round the tip of the platinum wire. Thus, in a particular case, with an inductance of 0.004 millihenry in the circuit of a Wehnelt break, no interruption of the circuit took place, but with one millihenry of inductance in the circuit, and with an electromotive force of 48 volts, the current became intermittent at the rate of 930 per second, and by increasing the voltage to 120 volts, the intermittency rose to 1,850 a second.

The Wehnelt break acts best as an interrupter with an electromotive force from 40 to 80 volts. At higher voltages a third stage sets in: the luminous glow round the platinum wire disappears, and it becomes surrounded with a layer of vapor, as observed by MM. Violle and Chassagny; the interruptions of current cease, and the platinum wire becomes red hot. If there is no inductance in the circuit, the interrupter stage never sets in at all, but the first stage passes directly into the third stage. In the first stage bubbles of oxygen rise steadily from the platinum wire, and in the interrupted stage they rise at longer intervals, but regularly. The cell will not, however, act as a break at all unless some inductance exists in the circuit.

In applying the Wehnelt break to an induction coil, the condenser is discarded and also the ordinary hammer break, and the Wehnelt break is placed in circuit with the primary coil. In some cases, the inductance of the primary coil alone is sufficient to start the break in operation, but with voltages above 50 or 60, it is generally necessary to supplement the inductance of the primary coil by another inductive coil. The best form of Wehnelt break for operating induction coils is the one with multiple anodes (see Dr. Marchant, *The Electrician*, Vol. XLII, page 841, 1899), and when it has to be used for long periods, the kathode may advantageously be formed of a spiral of lead pipe, through which cold water is made to circulate.

Another form of electrolytic break was introduced by Mr. Caldwell. In this, a vessel containing dilute sulphuric acid is divided into two parts. In the partition is a small hole, and in the two compartments are electrodes of sheet lead. The small hole causes an intermittency in the current which converts the arrangement into a break. Mr. Campbell Swinton modified the above arrangement by making the partition to consist of a sort of porcelain test-tube with a hole in the bottom. This hole can be more or less plugged up by a glass rod drawn out to a point, and this is used to more or less close the hole. This porcelain vessel contains dilute acid and stands in a

larger vessel of acid, and lead electrodes are placed in both compartments. The current and intermittency can be regulated by more or less closing the aperture between the two regions.

When the Wehnelt break is applied to an ordinary ten-inch induction coil, and the inductance of the primary circuit and the electromotive force varied until the break interrupts the current regularly, and with the frequency of some hundred a second, the character of the secondary discharge is entirely different from its appearance with the ordinary hammer break. The thin blue lightning-like sparks are then replaced by a thicker mobile flaming discharge, which resembles an alternating current arc, and when carefully examined or photographed is found to consist of a number of separate discharges superimposed upon one another in slightly different positions.

Many theories have been adopted as to the action of the break, but time will not permit us to examine these. Professor S. P. Thompson and Dr. Marchant have suggested a theory of resonance.* One difficulty in explaining the action of the break is created by the fact that it will not work if the platinum wire is made a kathode.

Although the Wehnelt break has some advantages in connection with the use of the induction coil for Röntgen ray work, its utility as far as regards Hertzian wave telegraphy is not by any means so marked. It has already been explained that, in order to charge a condenser of a given capacity at a constant voltage, the electromotive force must be applied for a certain minimum time, which is determined by the value of the capacity and the resistance of the secondary circuit of the induction coil. If the coil is a ten-inch coil and has a secondary resistance of say 6,000 ohms, and if the capacity to be charged has a value say of one thirtieth of a microfarad, then the time-constant of the circuit is 1/5,000 of a second. Therefore, the contact with the condenser must be maintained for at least 1/500 of a second, during the time that the secondary electromotive force of the coil is at its maximum, so that the condenser may become charged to a voltage which the coil is then capable of producing.

In the induction coil, the electromotive force generated in the secondary coil at the 'break' of the primary current is higher than that at the 'make,' and this electromotive force, other things being equal, depends upon the rate at which the magnetism of the iron core dies away, and its duration is shorter in proportion as the whole time occupied in the disappearance of the magnetism is less. The Wehnelt break does not increase the actual secondary electromotive force, nor apparently its duration, but it greatly increases the number of times per second this electromotive force makes its appearance. Hence this break increases the current, but not the electromotive force in the

* See *The Electrician*, Vol. XLII., 1899.

secondary coil. It therefore does not assist us in the direction required, viz., in prolonging the duration of the secondary electromotive force to enable larger capacities to be charged.

The important point in connection with the working of a coil used for charging a condenser is not the length of spark which the coil can give alone, but the length of spark which can be obtained between small balls attached to the secondary terminals, when these terminals are also connected to the two surfaces of the condenser. Thus, a coil may give a ten-inch spark if worked alone, but on a capacity of one thirtieth of a microfarad it may not be able to give more than a five-millimeter spark. Hence in describing the value of a coil for wireless telegraph purposes, it is not the least use to state the length of spark which the coil will give between the pointed conductors in air, but we must know the spark length which it will give between brass balls, say 1 cm. in diameter, connected to the secondary terminals, when these terminals are also short-circuited by a stated capacity, the spark not exceeding that length at which it becomes non-oscillatory.

A good way of describing the value of an induction coil for wireless telegraph purposes is to state the length of oscillatory spark which can be produced between balls one centimeter in diameter connected to the secondary terminals, when these balls are short-circuited by a condenser having a capacity say of one hundredth of a microfarad, and also one tenth of a microfarad.

If a hammer or motor interrupter is employed with the coil, then a primary condenser must be connected across the points between which the primary circuit is broken. This condenser generally consists of sheets of tin-foil alternated with sheets of paraffin paper, and for a ten-inch coil, may have a capacity of about 0.4 or 0.5 of a microfarad.*

Lord Rayleigh discovered that if the interruption of the primary circuit is sufficiently sudden and complete, as when the primary circuit is severed by a bullet from a gun, the primary condenser can be removed and yet the sparks obtained from the secondary circuit are actually longer than those obtained with the condenser and the ordinary break.†

In the use, however, of the coil for Hertzian wave telegraphy, with all interrupters except the Wehnelt break, a condenser of suitable capacity must be joined across the break points.

Turning in the next place to the primary key, or signaling interrupter, it is necessary to be able to control the torrent of sparks between

* For a discussion of the function of the condenser in an ordinary induction coil, see 'The Alternate Current Transformer,' by J. A. Fleming, Vol. II., p. 51.

† See Lord Rayleigh, *Phil. Mag.*, December, 1901.

the secondary terminals of the coil, and to cut them up into long and short periods in accordance with the letters of the Morse alphabet. This is done by means of the primary key. The primary key generally consists of an ordinary massive single contact key with heavy platinum contacts. As the current to be interrupted amounts to about ten amperes and is flowing in a highly inductive circuit, the spark at break is considerable. If the attempt is made to extinguish this spark by making the contacts move rapidly away from one another through a long distance, in other words, by using a key with a wide movement, then the speed at which the signals can be sent is greatly diminished. The speed of sending greatly depends upon the time taken to move the key up and down between sending two dots, and hence a short range key sends quicker than a long range key. If it is desired to use a short range key, then some method must be employed to extinguish the spark at the contacts. This is done in one of three ways: Either by using a high resistance coil to short-circuit these contacts, or by a condenser, or by a magnetic blow-out, as in the case of an electric tram-car circuit controller. Of these, the magnetic blow-out is probably the best.

Mr. Marconi has designed a signaling key which performs the function not only of interrupting the primary circuit, but at the same time breaks connection between the receiving appliance and the aerial.

The author has designed for signaling purposes a multiple contact key which interrupts the circuit simultaneously in ten or twelve different places. The particular point about this break is the means which are taken to make the twelve interruptions absolutely simultaneous. If these interruptions are not simultaneous, the spark always takes place at the contact which is broken first, but if the circuit is interrupted in a dozen places quite simultaneously, then the spark is cut up into a dozen different portions, and the spark at each contact is very much diminished. By this break, voltages up to two thousand volts may be quite easily dealt with.

Various forms of break have been devised in which the circuit is broken under oil or insulating fluids, but, generally speaking, these devices are not very portable, and a dry contact between platinum surfaces with appropriate means for cutting up the spark and blowing it out so that the mechanical movement of the switch may be small is the best thing to use.

The signaling key is really a very important part of the transmitting arrangement, because whatever may be the improvements in receiving instruments, it is not possible to receive faster than we can send. A great many statements have appeared in the daily papers as to the possibility of receiving hundreds of words a minute by

Hertzian wave telegraphy, but the fact remains that whatever may be the sensibility of the receiving appliance, the rate at which telegraphy of any kind can be conducted is essentially dependent upon the rate at which the signals can be sent, and this in turn is largely dependent upon the mechanical movement which the key has to make to interrupt the primary circuit, and so interrupt the secondary discharge.

In order to make the separation of the contact points of the switch as small as possible, and yet prevent an arc being established, various blow-out devices have been employed. The simplest arrangement for this purpose is a powerful permanent magnet so placed that its inter-polar field embraces the contact points and is at right angles to them.

As already explained, the applicability of the induction coil in wireless telegraphy is limited by the fact of the high resistance of the secondary circuit, and the small current that can be supplied from it. Data are yet wanting to show what is the precise efficiency of the induction coil, as used in Hertzian wave telegraphy, but there are reasons for believing that it does not exceed 50 or 60 per cent.

Where large condensers have to be charged, in other words, where we have to deal with larger powers, we are obliged to discard the induction coil and to employ the alternating current transformer. But this introduces us to a new class of difficulties. If an alternating current transformer wound for a secondary voltage, say of 20,000 or 30,000 volts, has its primary circuit connected to an alternator, then if the secondary terminals, to which are connected two spark balls, are gradually brought within striking distance of one another, the moment we do this an alternating current arc starts between these balls. If the transformer is a small one, there is no difficulty in extinguishing this arc by withdrawing the secondary terminals, but if the transformer is a large one, say of ten or twenty kilowatts, dangerous effects are apt to ensue when such an experiment is tried. The short circuiting of the secondary circuit almost entirely annuls the inductance of the primary circuit. There is, therefore, a rush of current into the transformer, and if it is connected to an alternator of low armature resistance, the fuses are generally blown, and other damage done.

Let us suppose then that the secondary terminals of the transformer are also connected to a condenser. On bringing together the spark balls connected with the secondary terminals, we may have one or more oscillatory discharges, but the process will not be continuous, because the moment that the alternating current arc starts between the spark balls, it reduces their difference of potential to a comparatively low value, and hence the charge taken by the condenser is very small, and, moreover, the circuit is not interrupted periodically so as to re-start a train of oscillations.

When, therefore, we desire to employ an alternating current trans-

former as a source of electromotive force, although it may have the advantage that the resistance of the secondary circuit of the transformer is generally small compared with that of the secondary circuit of an induction coil, yet nevertheless we are confronted with two practical difficulties: (1) How to control the primary current flowing into the transformer; and (2) how to destroy the alternating current arc between the spark balls and reduce the discharge entirely to the disruptive or oscillatory discharge of the condenser.

The control over the current can be obtained, in accordance with a plan suggested by the author, by inserting in the primary circuit of the transformer two variable choking coils. The form in which it is preferred to construct these is that of a cylindrical bobbin standing upon a laminated cross-piece of iron. These bobbins can have let down into them an E-shaped piece of laminated iron, so as to complete the magnetic circuit, and thus raise the inductance of the bobbin. By placing two of these variable choking coils in series with the primary circuit, the current is under perfect control. We can fix a minimum value below which the current shall not fall, by adjusting the position of the cores of these two choking coils, and we can then cause that current to be increased up to a certain limit which it can not exceed, by short-circuiting one of these choking coils by an appropriate switch. Several ways have been suggested for extinguishing the alternating current arc which forms between the spark balls connected to the secondary terminals when these are brought within a certain distance of one another. One of these is due to Mr. Tesla. He places a strong electromagnet so that its lines of magnetic flux pass transversely between the spark balls. When the discharge takes place the electric arc is blown out, but if the balls are short-circuited by a condenser, the oscillatory discharge of the condenser still takes place across the spark gap. Professor Elihu Thomson achieves the same result by employing a blast of air thrown on the spark gap. This has the effect of destroying the alternating current arc, but still leaves the oscillating discharge of the condenser. The action is somewhat tedious to explain in words, but it can easily be understood that the blast of air, by continually breaking down the alternating current arc which tends to form, allows the condenser connected to the spark balls to become charged with the potential of the secondary circuit of the transformer, and that this condenser then discharges across the spark gap, producing an oscillatory discharge in the usual manner. The author has found that without the use of any air blast or electromagnet, simple adjustment of the double choking coil in the primary circuit of the transformer as above described is sufficient to bring about the desired result, when the capacity of the condenser is adjusted to be in resonance.

Another method which has been adopted by M. d'Arsonval is to cause the spark to pass between two balls placed at the extremities of metal rods, which are in rapid rotation like the spokes of a wheel. In this case, the draught of air produced by the passage of the spark balls blows out the arc and performs the same function as the blast of air in Professor Elihu Thomson's method. When these adjustments are properly made, it is possible, by means of a condenser and an alternating current transformer supplied with current from an alternator, to create a rapidly intermittent oscillatory discharge, the sparks of which succeed one another so quickly that it appears almost continuous. When using a large transformer and condenser, the noise and brilliancy of these sparks are almost unbearable, and the eyes may be injured by looking at this spark for more than a moment. In the construction of transformers intended to be used in this manner, very special precautions have to be taken in the insulation of the primary and secondary circuits, and the insulation of these from the core.

It may be remarked in passing that experimenting with large high tension transformers coupled to condensers of large capacity is exceedingly dangerous work, and the greatest precautions are necessary to avoid accident. In the light, however, of sufficient experience there is no difficulty in employing high tension transformers in the above described manner, and in obtaining electromotive forces of upwards of a hundred thousand volts supplied through transformers capable of yielding any required amount of current.

On occasions where continuous current alone is available, a motor generator has to be employed converting the continuous current into an alternating current. This is best achieved by the employment of a small alternator directly coupled to a continuous current motor; or by providing the shaft of a continuous current motor with two rings connected to two opposite portions of its armature, so that when continuous current is supplied to the brushes pressing against the commutator, an alternating current can be drawn off from two other brushes touching the above mentioned insulated rings.

The next element of importance in the transmitting arrangement is the spark gap. In the case of those transmitters employing an ordinary induction coil, the secondary spark, or the discharge of any condenser connected to the secondary terminals can be taken between the brass balls about half an inch or one inch in diameter, with which the terminals of the secondary coil are usually furnished; and it is generally the custom to allow this spark discharge to take place in air at ordinary pressure. In the very early days of his work Mr. Marconi adopted the discharger devised by Professor Rhigi, in which the spark takes place between two brass balls placed in vaseline or other highly

insulating oil.* But whatever advantage may accrue from using oil as the dielectric in which the spark discharge takes place, when carrying out simple laboratory experiments on Hertzian waves, there is no advantage in the case of wireless telegraphy. The Rhigi discharger was, therefore, soon discarded. If discharges having large quantity are passed through oil, it is rapidly decomposed or charred, and ceases to retain the special insulating and self-restoring character which is necessary in the medium in which an oscillating spark is formed. The conditions when the discharges of large condensers are passed between spark balls are entirely different from those when the quantity of the spark, or to put it in more exact language, the current passing, is very small. In the case of Hertzian experiments, it is necessary, as shown by Hertz, to maintain a high state of polish on the spark balls when they are employed for the production of short waves of small energy, but when we are dealing with large quantities of energy at each discharge, those methods which succeed for laboratory experiments are perfectly impracticable. The conditions necessary to be fulfilled by a discharger for use in Hertzian wave telegraphy are that the surfaces shall maintain a constant condition and not be fused or eaten away by the spark, and, next, that the medium in which the discharge takes place shall not be decomposed by the passage of the spark, but shall maintain the property of giving way suddenly when a certain critical pressure is reached, and passing instantly from a condition in which it is a very perfect insulator to one in which it is a very good conductor; and, thirdly, that on the cessation of the discharge, the medium shall immediately restore itself to its original condition.

When using the ordinary ten-inch induction coil, and when the capacity charged by it does not exceed a small faction of a microfarad, it is quite sufficient to employ brass or steel balls separated by a certain distance in air, at the ordinary pressure, as the arrangement of the discharger. When, however, we come to deal with the discharges of very large condensers, at high electromotive forces, then it is necessary to have special arrangements to prevent the destruction of the surfaces between which the spark passes, or their continual alteration, and many devices have been invented for this purpose. The author has devised an arrangement which fulfils the above conditions very perfectly for use in large power stations, but the details of this can not be made public at the present time.

* It has sometimes been stated that the spark balls must be *solid* metal and not hollow, but this is a fallacy, and has been disproved by Mr. C. A. Chant. See 'An Experimental Investigation into the Skin Effect in Electrical Oscillators,' *Phil. Mag.*, Vol. III., Sec. 6, p. 425, 1902.

(*To be continued.*)

# WHY A FLAME EMITS LIGHT—THE DEVELOPMENT OF THE THEORY.

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As one would naturally suppose, the theory now generally held regarding the nature of an ordinary flame and its power to emit light is not altogether the result of modern research, but one which has been evolved from very ancient and hazy notions. Naught else is to be expected when we consider the important place fire has held throughout the development of mankind. It is the first recorded object of his worship, and we have reason to believe that all architecture had its beginning in rude structures erected to protect the sacred fire. It is not the nature of man to see phenomena so striking as those which attend the consumption of matter by fire and not speculate upon them. But the centuries had multiplied and modern times had been reached before man's ideas regarding fire, flame and light became distinct, and the use of these terms differentiated. The best text-books and works on natural philosophy published near the end of the eighteenth century still used the terms with great looseness, and the conceptions of the material nature of flame and light were yet in their death struggles.

After the corpuscular theory of light had given place to the wave theory, conflicting ideas arose as to why and how a flame emits light waves. When it was agreed that the waves were sent out by solid particles of carbon heated to incandescence, the question of the origin of the carbon, or the chemical changes taking place in the flame, was discussed, and along with this the source of heat which renders it incandescent. The last and most generally accepted answer to these two questions—the origin of carbon particles and the source of heat—is given in the 'acetylene theory,' first advanced in 1892 by Professor Vivian B. Lewes, of England.

This theory expressed briefly is that a portion of the hydrocarbon gas, by the heat of combustion of another portion, is converted into acetylene, and that this on being decomposed by heat furnishes the carbon particles, which particles are rendered incandescent mainly by the heat liberated when the gas is decomposed; acetylene being a substance which absorbs heat during its formation and hence liberates heat when it breaks down. Whatever is burned, whether a solid candle or liquid oil, must pass through the gaseous state, and hence this applies to all flames used for lighting purposes.

But before explaining this theory more fully and seeing upon what experimental evidence it is based, it would be well to consider its genesis and briefly recall the ancient notions regarding 'artificial' light.

Light was first confused with seeing, and it is said that up to the time of Aristotle men commonly thought they saw by reason of something shooting out from the eyes and coming in contact with objects; the converse of the Cartesian conception of many centuries later, that certain movements in bodies cause them to shoot out minute particles in all directions, which, striking the eye or causing 'globules' of air to strike it, excite vision.

The fluid nature of fire and the corporeal nature of light, which were believed in throughout the early and middle ages, seem to have been first doubted by Sir Francis Bacon about the end of the sixteenth century, although he was by no means sure that these conceptions were wrong. Bacon classed together the light from flames, decayed wood, glowworms, silks, polished surfaces, etc., and said that inasmuch as some animals can see in the dark, air has some light of itself. Boerhaave, somewhat later, also expressed doubts as to the substantive nature of fire.

Among the first recorded experiments upon the nature and action of luminous flames are those which were carried out by Sir Robert Boyle between 1660 and 1670. He attempted to prove by experiment whether the light from a flame is like that from the sun, and whether it is corporeal or merely a quality. He allowed a flame to play on metals directly and also when in open and sealed vessels, and because the substance formed a calx and gained in weight, he thought that the light or flame (he uses the terms indiscriminately) had combined with the metal, and hence it must be a fluid. Boyle also conducted a large number of experiments upon live or 'quick' coals, phosphorescent bodies, animals and insects to see the effect of exhausting a receiver in which they were placed, and he seems to have concluded that the lights from live coals, rotten wood and putrefying fish differ not in kind but only in degree. He considered that the increase of light from coals, etc., and the reviving of certain insects when air was readmitted to the receiver indicated a relation between a visible flame and the so-called 'vital flame.' But he would not commit himself upon the question of the supposed kinship between the 'flame' from live coals and rotten wood and the 'vital flame' thought to be burning in the hearts of all living beings.

The interesting views of Sir Isaac Newton are set forth in a number of queries published in his work entitled 'Optics.' As is well known, Newton believed in the material nature of light, and he asserted that the change of light into matter and of matter into light is an acknowledged possibility and of common occurrence. He attributed the light

which appears when a body is rapidly and repeatedly struck or when heated beyond a certain point, as when flint and steel are struck together, etc., to vibrations of the parts of the body so rapid as to throw off the particles which, according to Newton's idea, occasion the sensation of light. With these he also classed electric sparks, saying that the 'electric vapor' excited by rubbing glass dashes against a strip of paper or the end of the finger held to it, is thereby so agitated as to cause it to emit light. He thought the light from glowworms and putrefying matter was of the same kind as the above, and said that the light seen at night in the eyes of certain animals, cats for instance, is 'due to vital motions.'

Regarding true luminous flames Newton's ideas were nearer those of the present time. He wrote "Is not fire a body heated so hot as to emit light copiously? For what else is a red hot iron than fire? And what else is a burning coal than red hot wood?" "Is not flame a vapor, fume or exhalation heated red hot, that is, so hot as to shine? For bodies do not flame without emitting a copious fume, and this fume burns in the flame. Metals in fusion do not flame for want of a copious fume." "All fuming bodies, as oil, tallow, wax, wood, etc., by fuming waste and vanish into burning smoke." 'Put out the flame and the smoke is visible, it often smells; and the nature of the smoke determines the color of the flame.' "Smoke passing through flame can not but grow red hot, and red hot smoke can have no other appearance than that of flame."

During the hundred years, more or less, following the publication of Newton's views there was little change in the prevailing theories. Stahl said 'flame is light' liberated from bodies in the act of combustion, and that light and heat are the constant attendants of fire; fire combined with combustible matter was 'phlogiston.' Scheele said light, heat and fire are combinations of air and 'phlogiston.' Lavoisier thought flame to be light disengaged from air, with which it had been in combination, and this idea seems to have been adopted by most of the French chemists.

There might be mentioned in this connection the queer ideas regarding our being able to see objects, and the emission of light by incombustible bodies, which were held during the latter half of the eighteenth century. As expressed by Macquer, and quoted by Fourcroy,* "The vibrations (under the impulse of more or less heat) dispose the particles (of bodies) in such a manner that their faces, acting like so many little mirrors, reflect upon our eyes the rays of light which are in the air by night as well as by day; for we are involved in darkness during the night for no other reason but because they are not then so directed as to face our organs of sight."

* Fourcroy's 'Chemistry,' press date 1796.

At a single step we pass from the rather crude ideas of the older thinkers to those ideas which obtain at the present day, and the transition finds little expression in the literature.

About the year 1816 Sir Humphry Davy advanced what has been known ever since as the 'solid particle' theory of luminosity; a theory which went unchallenged for forty-five years and was accepted by practically every one.

He was experimenting upon the combustion taking place in his famous safety lamp and said, "I was led to imagine that the cause of the superiority of the light of a stream of coal gas might be owing to the decomposition of a part of the gas towards the interior of the flame, where the air is in smallest quantity, and the deposition of solid charcoal, which, first by its ignition and afterwards by its combustion, increased to a high degree the intensity of the light; and a few experiments soon convinced me that this was the true solution of the problem." "Whenever a flame is remarkably brilliant and dense, it may always be concluded that some solid matter is produced in it; on the contrary, whenever a flame is extremely feeble and transparent it may be inferred that no solid matter is formed." The idea that solid carbon in the flame is the source of its light was not original with Davy—he says it was suggested by a Mr. Hare—but it was Davy's investigations which put it on a firm basis and he formulated the theory.

Davy showed the relation between the heat and light of flames, the effects of rarefaction and compression of the surrounding air and the influence of cooling and heating. He pointed out also that a luminous flame will deposit carbon on a cold surface, and if rendered non-luminous no carbon can be obtained. These conclusions were immediately accepted and were not seriously disputed until the appearance in 1861 of a communication to the Royal Society from E. Frankland.

In this article Frankland advanced what has come to be known as the 'dense vapor' theory. He and his adherents claimed that, although solid particles in a flame do cause it to emit light, the light from our ordinary illuminating flames is dependent to a great extent upon the presence of dense, transparent, hydrocarbon vapors from which it is radiated, and is not due to the presence of incandescent solid carbon particles. They further claimed that the soot deposited is not carbon, but a mixture of dense hydrocarbons of remarkably high boiling points.

Frankland was led to take up his investigations by seeing a report that candles burned at the same rate on the top of Mt. Blanc as in the valley at its foot; and a second report regarding the retardation of the bursting of shells with time fuses at high elevations in India.

Besides carrying on investigations in artficially rarefied air in his laboratory, he climbed to the top of Mt. Blanc with a goodly supply of standard candles and timed their slow wasting away; probably keeping

warm in the meantime by the fire of his enthusiasm. Many interesting facts were brought to light by these investigations, but his use of them in interpreting the causes of luminosity in ordinary flames led him into error, and, although he found adherents at the time, his views have long since been replaced by those based upon more careful observation. The importance of the work of Frankland lay not so much in what he did as in what he led others to do; and since the publication of his views a great deal has been done by Heumann, Stein, Smithells, Burch, Lewes and others.

Stein disproved Frankland's assertion that soot is a mixture of dense hydrocarbons by showing that it can not be volatilized even by great heat, and that it contains only about nine tenths of one per cent. of hydrogen, which can be separated from it only at high temperatures in an atmosphere of chlorine.

Nor did Frankland's view that glowing, dense vapors cause the light appeal to Heumann, who thought it unlikely that such dense vapors exist in a flame or that there is a sufficiently high temperature to cause them to glow. He knew, of course, that at a temperature like that of an electric arc many gases do glow and give continuous spectra, and that a highly heated gas under pressure acts likewise; but he argued that if carbon really does exist as such in a flame, it most probably is the source of luminosity. To prove its presence or absence he studied the effects upon a flame of heating and cooling it, of diluting and varying the temperature of the gases supplied to it, its transparency and the shadows cast by it, as well as other phenomena; and the results of his experiments led him to give unqualified support to the theory of Davy.

Some account of the salient features at least of Heumann's elaborate investigation must be given in order to convey any idea of his part in firmly fixing the 'solid particle' theory. By allowing a luminous flame to play upon a surface which rapidly conducted heat away from it, like a platinum dish, its luminosity was destroyed. Heating the upper surface of the dish restored the luminosity, and hence Heumann concluded that cooling a flame diminishes its light-giving properties, while heating increases them. He varied the temperature of illuminating gas before it reached the burner and found that the same effects were produced. The heating in some cases increased the normal light-giving power as much as a hundred and twenty-five per cent. Further investigation showed that luminosity can also be diminished or destroyed by rapid oxidation of the hydrocarbons, as well as by diluting them with a neutral gas like nitrogen or carbon dioxide; the effect of dilution being to necessitate a higher temperature for luminosity. He next rendered a flame non-luminous by cooling, introduced chlorine into it to break down the hydrocarbons, and obtained a brilliant light.

A porcelain rod introduced into the lower part of a flame cooled it and decreased its light, but collected no carbon, while, if introduced into the upper part, its *under side* became coated with soot. Heumann argued that if Frankland was right and the light is reflected from dense hydrocarbon vapors, these should be condensed on all sides of the rod at once in a quiet flame, while, as a matter of fact, soot was deposited only on the under side; and furthermore, soot can also be collected upon a surface too hot to condense hydrocarbons at all. He therefore concluded that the surface merely stops carbon which is formed lower down in the flame. If one luminous flame is allowed to play against another, the carbon is rolled up and can be seen as glowing particles in the outer non-luminous sheath.

Frankland had said that flames can not contain solid particles because they are transparent. Heumann pointed out that thick flames are opaque and that thin ones are no more transparent than is an equal layer of soot rising from burning turpentine; the rapidity of the motion of the particles preventing any obstruction to the view, just as is the case with a rapidly revolving, spoked wheel.

Heumann next took up the phenomena of shadows and showed that the luminous portion casts a definite shadow when interposed between sunlight and a screen, and that the shadow is continuous for a luminous turpentine flame and the column of soot above it. And further, that a hydrogen flame which ordinarily casts no shadow and gives no light will cast a sharp shadow and emit a fairly bright light if passed through suspended lampblack or if it sweeps any solid matter into the flame. Luminous vapors do not cast shadows, absorption bands being very different from true shadows.

C. J. Burch found that when sunlight is reflected from a luminous flame it is polarized, while if reflected by glowing vapors, however dense, it does not exhibit this phenomenon. Sunlight which was reflected and refracted by luminous flames was found to exhibit phenomena identical with that reflected and refracted by non-luminous flames rendered luminous by the introduction of solid matter, and also with light reflected and refracted by very finely divided solid matter held in suspension in a liquid. The phenomena presented by like experiments with glowing vapors were totally different. All of Burch's work was confirmed by Stokes some years later.

There was now left no shadow of doubt about carbon being the source of the light rays, and the next question that concerned investigators was the chemical changes which give rise to carbon particles.

Sir Humphry Davy thought the separation of carbon to be due to a decomposition of the hydrocarbon compounds (of which all illuminants are composed) within the flame where the air is in smallest quantity, and no other cause was assigned by other investigators. Prior to

1861 the view, it seems, was that carbon is liberated because of a supposed greater affinity of oxygen for the hydrogen of the hydrocarbon than for the carbon, there not being enough for both. But these points had to be tested.

In the study of the chemical changes that take place, a flame burning at a circular orifice offered the best conditions. As explained in text-books of chemistry, such a flame may be thought of as being made up of an inner, faintly luminous cone fitting into an outer, brightly luminous one—as a finger fits into a glove finger—this latter being surrounded by a non-luminous sheath of water vapor and carbon dioxide. It was desirable to separate these two cones, in order to study the gas after it had left the inner cone and before any change had been brought about by the conditions existing in the outer cone. This separation was first accomplished by Techlu, in France, and Arthur Smithells, in England, working independently, with a piece of apparatus, the essential features of which are pictured in cross-section in Fig. 1. By a proper control of the relative proportions of gas and air the inner cone was made to burn at the orifice *i*, while the outer cone burned at the orifice *o*. The outer cone got its oxygen from the surrounding air, while that for the lower flame was supplied along with the gas. The temperature of each cone was measured and the gases entering and leaving each were analyzed. It was found that as the proportion of gas to air was increased, the tip of the inner or lower cone became *brightly* luminous and a column of soot passed upward through the tube, becoming *faintly* luminous in the outer edge of the upper flame. As soon as the inner cone becomes luminous the unsaturated* hydrocarbon compound known as acetylene begins to appear among the gases passing to the outer cone.

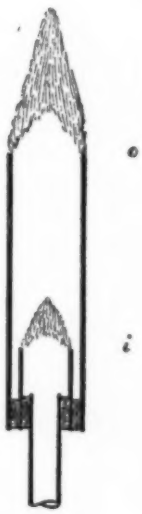


*Fig. I.*

Vivian B. Lewes now attacked the problem as to how carbon comes to be in the flame in the free state. He analyzed gas drawn from different parts of a coal-gas flame, measured the temperature of its different parts, etc., publishing his results between 1892 and 1895. These results may be stated as follows: Coal-gas consists mainly of a mixture of hydrogen and hydrocarbons, both saturated and unsaturated. In an ordinary 'fishtail' burner flame all hydrogen is consumed before the middle of the luminous portion is reached. Of the *saturated* hydrocarbons about seventy-five per cent. disappears as such in the dark por-

* The terms 'saturated' and 'unsaturated' have reference, among other things, to the relative quantity of hydrogen to carbon in the molecule, an unsaturated compound having relatively less hydrogen than a saturated one.

tion and about twenty-four per cent, is lost in the lower half of the luminous part. In the dark part there occurs a transformation of saturated into unsaturated hydrocarbons, along with a general breaking down of all to yield products less rich in hydrogen and the oxides of carbon. At the point where luminosity just begins, seventy to eighty per cent. of the unsaturated compounds is acetylene, although less than one per cent. was originally present. No acetylene could be found in the flame when it was made non-luminous.

By causing pure gases to pass through tubes heated to known temperatures and analyzing the products formed, Lewes studied the effects of heat upon both saturated and unsaturated hydrocarbons. At 800° C. an unsaturated compound, like ethylene, $C_2H_4$, breaks down into hydrogen and the still more unsaturated acetylene, $C_2H_2$. At 1200° C. the very stable, saturated hydrocarbons decompose into acetylene and hydrogen, and the acetylene in turn decomposes into carbon and hydrogen. Even very dense hydrocarbons decompose at 1200° C. These results strengthened Lewes's conviction that under the baking action of the flame-walls in the lower portions acetylene is produced in relatively large quantities and that this is the source of the carbon.

The question which immediately presented itself was, Does there exist in an ordinary flame such conditions of temperature as may bring about the formation of acetylene from the very stable constituents of the illuminants? On measuring the temperatures at various places the necessary temperatures were found to exist.

The work was complete and conclusive and forced a general acceptance of the theory that acetylene is the immediate source of the carbon.

But a yet harder problem presented itself, What gives rise to heat sufficient to make the carbon become incandescent?; a burning question certainly and one not easy to answer.

From the time of Davy to the year 1892 the only opinion was that the burning hydrogen, carbon monoxide and hydrocarbons furnished the heat necessary to raise carbon to incandescence. In that year Lewes advanced his 'latent heat' theory. This theory declared that the latent heat set free when acetylene is decomposed instantly heats the carbon particles thus set free to incandescence.

After showing that the heat of combustion of a flame is only sufficient to render carbon faintly luminous, Lewes compared the temperatures of flames burning coal-gas, the unsaturated hydrocarbon gas, ethylene, and the still less saturated acetylene, and also the amount of light given by each when burning equal volumes of gas per hour from burners best suited to each. He likewise studied the temperatures developed when acetylene is exploded and the localization of the heat set free by its decomposition. His experiments were ingenious and con-

vincing. By comparing ethylene, $C_2H_4$, with acetylene, $C_2H_2$ (where for equal consumption the same number of carbon atoms were present), and also with coal-gas, it was seen that the luminous portion of the acetylene flame is not as hot as that of either ethylene or coal-gas, while the illuminating powers of the flames were: acetylene, 240.0 candle power, ethylene, 65.5 c.p. and coal-gas, 16.8 c.p. Evidently the heat of combustion does not account for the incandescence of the carbon; for if it did the cooler acetylene flame would give less light, while, as a matter of fact, it gives twice as much as the ethylene and about fourteen times as much light as the very much hotter coal-gas flame. It was evident that our temperature measuring instruments do not detect the heat of the carbon particles themselves.

To see if luminosity be even partly due to the latent heat of acetylene, Lewes exploded that gas in a closed tube. This was done by wrapping a bit of fulminate of mercury in tissue paper and suspending it by copper wires joined by platinum in contact with the fulminate, and passing an electric current. There followed a brilliant flash of light and a complete decomposition of the gas, and of the eudiometer as

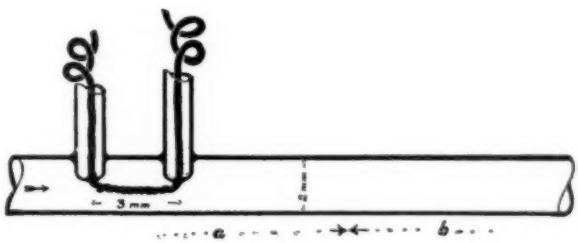



*Fig. II*

well. Pieces of glass were coated with carbon, and the tissue paper was not scorched except in a small hole where the explosion of the fulminate had burst through. This experiment showed the formation of carbon, the emission of a brilliant light and the localization of the heat liberated. But as the decomposition in a flame can hardly be as rapid as in this experiment, and as hydrogen and oxygen also give a feeble light when exploded, he sought to detect the rise in temperature at the moment of decomposition when this is caused by heat. He arranged a thermo-couple in a small tube so that only the turn of wires was exposed, and after sweeping out the air passed a slow current of acetylene through the tube, the arrangement being as shown in Fig. 2. The heat was raised throughout the tube at a rate of about 10° C. per minute, and almost as soon as the temperature of area *a* passed 800° C. it took a sudden leap to 1000° C., the gas burst into a lurid flame and streams of carbon passed on through the tube. Although the temperature of area *b* was made considerably higher than *a* the carbon

passing through it was not luminous. This experiment would seem to leave no doubt that the incandescence is caused by latent heat, yet further evidence was produced. In another experiment in which diluted acetylene was used it required a higher heat to cause the decomposition and luminosity. This latter is the condition existing in a flame, and the temperature there found is above that required. In other experiments it was found that if the flame temperature were high enough the luminosity was directly proportional to the amount of acetylene in the flame *at the point where luminosity generally begins.* Acetylene was introduced at the corresponding place in a non-luminous flame through very fine holes in a small capillary platinum tube, and the rate of its flow, as well as that of the illuminating gas, was measured and controlled so as to have present the amount of acetylene, which analysis showed to exist in a similar luminous flame. At the holes there was an intense light, and dull red streams of carbon passed upward in the flame.

Lewes sums up his conclusions, drawn from all his work, about as follows: When the hydrocarbon gas leaves the jet at which it is burned, those portions which come in contact with the air are consumed and form a wall of flame, which surrounds the issuing gases. The unburnt gas in its passage through the lower heated area undergoes a number of chemical changes, brought about by the heat radiated from the flame walls; the principal change being the conversion of hydrocarbons into acetylene, hydrogen and methane. The temperature of the flame rapidly increases with the distance from the jet and reaches a point at which it is high enough to decompose acetylene into carbon and hydrogen with a rapidity almost that of an explosion. The latent heat so suddenly set free is localized by the proximity of carbon particles, which by absorbing it become incandescent and emit the larger part of the light given out by the flame; although the heat of combustion causes them to glow somewhat until they come into contact with oxygen and are consumed. This external heating gives rise to little of the light.

There have been opponents to this theory of the cause of luminosity —as there are, fortunately, of all theories—but the evidence is so strong and covers so many points, and so many investigators have confirmed one part or another of the work, that it has been generally accepted as a true statement of the facts with which it deals.

# EVOLUTION, CYTOLOGY AND MENDEL'S LAWS.

BY O. F. COOK,

U. S. DEPARTMENT OF AGRICULTURE.

THE debt of science to theory is a truism. Bad theories are only less valuable than good ones, and for some purposes they are even better. We do not arrive where we expected to go, but reach an undiscovered country which a more direct route would have left unexplored. The recent history of biology furnishes two excellent examples of the fertility of false theories in the development of the related sciences, embryology and cytology. The theory of organic recapitulation, to the effect that the phylogeny or evolutionary history of natural groups must be repeated in the ontogeny or development of each individual organism promised the student of embryology an easy wealth of scientific discovery, and within a few years hundreds of razors were paring thin the mysteries of evolution. Libraries of new facts were discovered and published, but as our knowledge of life histories increased there was a corresponding decline in the probability that any particular stage in the growth of the individual is necessarily more ancestral than any other. That no general doctrine of recapitulation could be maintained was perceived by Sir John Lubbock as early as 1873,* but vertebrate embryologists did not permit their zeal to be dampened by even the most obvious facts of entomology. Indeed, one of our prominent investigators, finding that recapitulation is elusive by microscopical methods, now proposes to test it by breeding experiments, the results of which may be available in a future geologic epoch.†

The organism having been followed back to its unicellular stage without discovering any process or mechanism by which its adult form was predetermined, believers in such a device must needs seek it inside the cell, and thus was opened another highly fertile field of investigation. Instead of mere homogeneous jelly, surprisingly complicated intracellular structures and processes have been discovered and described, and to identify some of these as the long-sought 'hereditary mechanism' is now the dream of the cytologist.

To judge from his recent article on 'Mendel's Principles of Heredity and the Maturation of the Germ-Cells'‡ Professor Wilson,

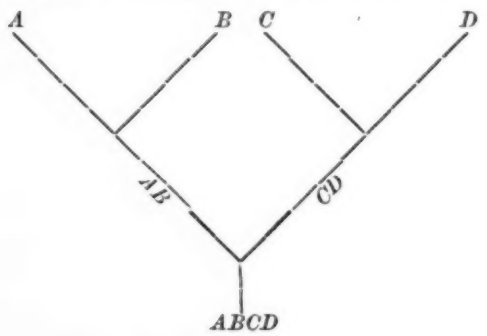
* 'Origin and Metamorphoses of Insects.'

† *Science*, N. S., 16: 506, September 26, 1902.

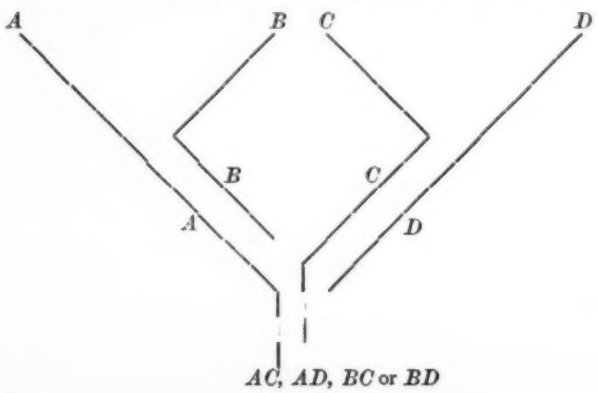
‡ *Science*, N. S., 16: 991, December 19, 1902.

at least, is still very strongly of the belief that the investigator of reproductive cells holds the keys of evolution, and he even finds it remarkable that a general cytological explanation of these 'principles of inheritance' was not suggested before. According to Professor Wilson the facts discovered by Mendel, that in some hybrids, characters of the parents are not permanently combined, are explainable by the 'normal phenomena of maturation,' that is, if we admit that 'individual chromosomes stand in definite relation to transmissible characters,' and that the 'reducing division' by which the reproductive cells are formed 'leads to the separation of paternal and maternal elements and their ultimate isolation as separate germ-cells.' This would be important if true, but the Mendelian facts are unable to accept this proffered support of cytological theory, because they have already demonstrated its falsity.

The commonly accepted view of organic descent may be illustrated by a simple diagram which indicates that a single individual may




inherit characters from all four of its grandparents. Professor Wilson's explanation of Mendel's law would deny this possibility, and would limit the descent of all individuals to two grandparents, so that the form of our family tree would be completely altered.



It would be impossible to have any such compound as *ABCD*, but we should get instead one of the four character-combinations *AC*, *AD*, *BC*, *BD*. The inheritance of a single character from one grandparent would certify the inheritance of all, and thus establish an alibi for the other ancestor of the same side of the house. What a resource for genealogists to be able to prove that a man was no relative of his grandfather, or even that he had no consanguinity with his own brother! Alas that Mendel and other 'experimental evolutionists' have proved that inheritance is by characters and not by chromosomes, if these behave as Professor Wilson indicates. Only the so-called monohybrids, those differing by a single character, would tolerate such an interpretation, and the fallacy of it is obvious as soon as we remember that hybrids may be assembled with reference to two, three or more characters derived from different ancestors. Moreover, Professor Spillman has recently drawn from his experiments with wheat concrete and detailed examples of the fact that definite proportions of such combinations are permanent, since two dominant characters do not antagonize each other.* Unless it be in the case where the varieties crossed differ in but a single character we know of a certainty that the germ-cells are not of pure descent with respect to *parentage*.† The most that can be claimed is that they are organized reciprocally with reference to the *divergent parental characters*, since it seems that the different features may be distributed and recombined quite without reference to the manner in which they were grouped in the parents. In his hybrid wheats Professor Spillman finds all the combinations possible under the mathematical theory of chance. How this could be managed by the chromosomes our cytological friends may be able to conjecture, though from the outside it looks like a rather difficult question.

Hybridization is possible only between groups of common origin, and the characters which show the Mendelian effect are those on which the greatest divergence has taken place. That such characters may be changed about or substituted, and are able to enter freely into all varieties of combination, not only does not prove that the chromosomes are mechanisms of heredity, but it greatly decreases the probability of mechanical theories of evolution, since it shows the facility with which characters may be accumulated in normal interbreeding, before the Mendelian degree of divergence has been reached.

If two plants different in other respects are found to differ also in

* 'Mendel's Law,' POPULAR SCIENCE MONTHLY, 62: 269.

† The theory of Bateson that the germ-cells are pure *with respect to characters* seems to have been misunderstood both by Professor Wilson and by Mr. Cannon in his 'Cytological Basis for the Mendelian Laws' (*Bulletin Torrey Botanical Club*, 29: 657, 1902).

chromosomes this does not prove that the chromosomes cause the other differences, even though the differences of the chromosomes interfere with the conjugation of the reproductive cells and thus prevent the hybridization of the plants. Species or varieties seldom, if ever, differ by single characters or at one stage merely, and there is no known reason why related species should not diverge in their single-celled condition as well as at any later period. It is rapidly becoming apparent that the internal organs and functions of cells are as diverse as those of embryos and adult organisms, and as much in need of a general evolutionary explanation.*

The notion that heredity, variation or other phases of evolution are the functions of special organs or mechanisms of cells, has no ascertained basis of fact, and is but an inference from the traditional evolutionary errors that species are normally constant or stable, and that developmental changes are the results of external influences. To move a stationary organism some sort of 'hereditary mechanism' would be needed to bring about the inheritance of characters 'acquired' from the environment, but if we consider that the individuals of a species are normally diverse, and that the species as a whole is normally in motion, a 'hereditary mechanism' becomes quite superfluous, or may be identified with the organism itself, whether in a unicellular or a polycellular stage.

Heredity is the term under which we allude to the fact that organisms exist in series of similar individuals; we have as yet no warrant for holding that it is special 'force' or agency. Crystals of the same substance are thought of as repeatedly taking the same form because of certain properties of matter, not because of a special crystallizing mechanism. The analogy of crystals is, of course, quite inadequate for biological purposes, but we need not reject it entirely, since for all purposes of expression heredity is a general property of living things, and with these there is even less reason than with crystals to seek a cause in the function of a special organ.

Inorganic elements and compounds are homogeneous and similar in all masses or parts; but diversity is the rule among organisms, no two of which are exact duplicates. The idea of a heredity which maintains identity of structure or form represents no fact in nature. The necessity of continued readjustment is general in life, and is not confined, even in complex organisms, to preliminary stages or to reproductive cells. The individual is not constant nor permanent, but has its own cycle of growth, reproduction and decline, accompanied by continuous changes in all parts of the bodily form and structure.

* Chromosome differences utterly disproportional to the differences of the adult organisms have recently been described by Monkhouse in hybrid fish eggs.

Organisms are not made up merely by the few characters enumerated by the systematist; an infinite number of differing relations of parts might be formulated. Evolutionary divergence is not confined to external adult characters, but may appear in any structure, function or instinct, and at any time in the life history. Species very different as adults may have closely similar young, or larvæ may be much more diverse than the mature insects. Only the inadequacy of our notions of the vital structure and activities has led us to expect that reproductive cells will be found to contain special 'hereditary mechanisms' for the predetermination of the characteristics of adults. The largest and most complex individuals are still groups of cells, and no adequate reason has been shown for believing that particular cells or links of the organic sequence are more hereditary or more determinant than the others. Characters are to be thought of as lines of biological motion, not as structures or entities of reproductive cells. The predetermination of the infinity of structural and morphological characters and positional relations of the millions of cells of the adult by a working model resulting from the conjugation of sexual elements may be dismissed as a crudely anthropomorphic notion of biological processes, as unsupported by facts as it is illogical in conception. Cells have their functions and organs, but evolution is not confined to these; it is also a supercellular or organic process. Cytology is a very interesting branch of descriptive biology, but it enjoys no special evolutionary facilities.

Polycellular organisms grow by the division of cells; but instead of proving that all cells divide in the same way cytologists have found that the same result may be accomplished by a great variety of protoplasmic organs and processes. Unicellular organisms are known to be extremely diverse cytologically, and the cells of compound organisms are, if possible, more so. We know also that the diversity of organisms is not due so much to differences of the individual cells as to differences of number and arrangement in the cell-colonies of which they are constituted.

Heredity is the unknown means by which successive generations of organisms are able to construct themselves in similar, though not identical, forms; it is, in short, an organic memory, and is responsible, not alone for the repetition of the structural type, but also for vast numbers of involuntary functional coordinations and instinctive acts, whether of unicellular or of compound organisms, or of whole colonies of organisms. A colony of social termites is as truly an evolutionary unit as a tree with its many branches, and the cooperative instincts which pervade the individual insects are as truly a hereditary phenomenon as the peculiar arrangement of branches which we term a 'character' of the tree.

To compare heredity with memory explains nothing, of course, since we know as little of the physical basis of the one as of the other, but if the analogy be admitted it will prevent the too confident insistence upon the theory that heredity depends entirely upon positional or other mechanical relations of molecules, or is in some way embodied in particular granules or chromosomes.

But even the most fantastic theories often have some basis of suggestion in fact, and although we can not accept Professor Wilson's cytological explanation of Mendel's laws, nor even share his hope that cytology will elucidate evolution, it is by no means impossible that the normal individual diversity of organisms has a cytological as well as an evolutionary significance. That normal development or growth by cell division is advantaged by cross-fertilization may mean that the cells divide more readily and normally when they contain protoplasmic 'elements' of a proper degree of diversity than when they have only one kind of protoplasm, as would happen in narrow inbreeding, and also when cross-breeding is too wide for the intimate cooperation required for true fertilization. The Mendelian effect would then be explainable on the suggestion of a partial cooperation which has to be abandoned in the formation of new individuals, because, while the organism can follow either of two diverging parental roads with respect to any character, it is, as it were, a stranger to the path that an average would require.

The conjugation of cells may be viewed as a process quite distinct from reproduction, though it is a necessary preliminary to the long series of cell divisions required to build up the complex bodies of the higher animals and plants. As we descend in the organic scale the conjugating cells become more and more similar to each other and to the so-called vegetative or somatic cells of which the body of the organism is composed. Among simple organisms all the cells are alike, including those formed immediately before and after conjugation, and it is not strange that with the diversification of the cells which constitute the various tissues of the plant or animal body the germ cells should become specialized and unlike any of the others. The existence of special reproductive cells among the higher animals and plants is therefore to be looked upon as corresponding to the general complexity of the organism, rather than as an indication of a special mechanism of heredity resident in the germ cells. As founders of new cell-colonies or compound individuals they develop, it appears, on one or the other of divergent parental lines instead of striking out on an untraveled road between.

Notwithstanding their great significance Mendel's laws are negative rather than positive in their bearing upon descent, since we do

not learn from them the nature of that process, but one of its limits. Moreover, the probability that these laws are of general application is greatly lessened by the fact that they are demonstrable only in connection with narrowly inbred and much divergent varieties of plants and animals, to which condition of the experiment the phenomena discovered may prove to be due, rather than to any general fact or mechanism of heredity. It seems certain, however, that neither theory nor experiment will make permanent progress in this direction as long as we continue to confuse under the word hybrid several extremely diverse evolutionary conditions, and fail to realize that generalizations based on any one kind or type of hybrids are quite premature and irrational.

*Sterile Hybrids.*—The original notion of a hybrid, or at least the most popular meaning of the term, is that of a cross between organic types so widely diverse that the progeny are in some way abnormal or defective, especially with reference to reproduction. Among animals sterile hybrids can not be propagated, but in plants they can be grown from cuttings or buds, and are thus preserved as horticultural 'varieties.'

*Aberrant Hybrids.*—The second and succeeding generations of hybrids not completely sterile often show striking deviations from both parental types. As these new characters are analogous to the abrupt variations of close-bred plants described by Darwin as 'sports' and more recently renamed 'mutations' by De Vries, it has been suggested that they may be due to the same causes, that is, they may not be in reality the result of crossing, but rather of an inadequate conjugation or defective fertilization which allows a lapse from the normal form. Both mutations and mutative hybrids are comparatively infertile, so that their suddenly attained new characters should not be looked upon as true contributions to evolutionary progress.

*Reciprocal or Mendelian Hybrids.*—Mendel and his successors have proved that there is still a third type of less abnormal hybrids, in which there is no permanent combination or averaging of divergent parental characters, although it is not known that vigor and fertility are notably diminished. Mendel's so-called laws are generalized statements of the results of his experiments upon the crossing of different garden varieties of the pea; he himself found that the same was not true among hybrids of *Hieracium*.* A part of the scientific com-

* The question has been raised as to whether Mendel's discoveries should be called 'laws.' The present view would deny to them universal application as 'laws' or 'principles' of heredity, though it admits as probable their general truth for a certain evolutionary condition or stage.

Laws of gases are not called laws of matter, and do not apply until matter reaches the gaseous state. Similarly, there can be no objection to

munity which a few years ago was properly characterized as more Darwinian than Darwin might now be described as more Mendelian than Mendel, and expects to find in 'Mendel's laws' an explanation of heredity, to say nothing of other things. Crosses between some twenty-six close-bred varieties of plants and animals have been found to 'Mendelize,' as the new expression is, and it may be expected that others will do the same wherever the conditions of the experiment can be met, though no amount of similar facts would justify the general conclusions which some recent writers have so promptly drawn. 'Mendel's laws' have already had many different statements, but the most that can be said with certainty is that after close-bred varieties of a plant or animal have sufficiently separated, their divergent characters do not again blend or reduce to an average, but draw apart into definite proportions of each succeeding generation of offspring. Obviously, this is not a method or law of inheritance, but of non-inheritance or fractional inheritance. The sterile and aberrant hybrids are evidence that too wide crossing is not advantageous and makes no contribution to evolutionary progress. Mendel's experiments afford further evidence of the same fact, in that the organisms themselves are found to have means of dissolving such alliances and thus of holding to the paths on which their varietal divergencies have gone forward. The theory that hybridization assists evolution by encouraging variability is shown to have a distinct limit, since little evolutionary progress would come from mere combination of the stable or divergent characters which are a prerequisite of the Mendelian experiments.

*Synthetic or Blended Hybrids.*—If the normal flexibility of the organism has not been diminished by narrow segregation or inbreeding, the Mendelian repugnance of divergent characters does not appear; Mendel's law of reciprocal characters gives place to Spillman's law of blended or graded characters.* Thus there is no record of a normal straight-haired white child as the offspring of two mulattoes. Inbreeding to an extent far beyond anything usual in nature is the rule among domesticated plants and animals, but if the varieties are not too divergent they cross freely and with obvious advantage, as shown by increase in vigor, though such 'new characters' soon disappear under renewed inbreeding. Characters which would become dominant in the Mendelian hybrids are in the less divergent stages termed prepotent, that is, they are impressed with increased intensity upon increasing numbers of each successive generation. On the other

such expressions as 'Mendel's laws of the disjunction of characters in hybrids,' or 'Mendel's laws of reciprocal hybrids.'

* ' * * * hybrids show every possible gradation between the characters of the two parents.'

hand, characters acquired through inbreeding or other debilitating causes may disappear or become recessive as soon as crossing permits a return to a more normal and vigorous ancestral type of organization, as in the historic pigeon experiments of Darwin. The popularization of Mendel's laws should make it more easy to perceive that the normal effect of cross-breeding is a progressive synthetic evolution and not a stationary average, though we are having some fine examples of the lengths to which the specialist will sometimes go to escape facts too simple and obvious for his appreciation.

*Individual 'Hybrids.'*—Perhaps the loosest use of the word hybrid is for the offspring of crosses between so-called 'horticultural varieties' of domesticated plants propagated by cuttings or grafts. Everybody knows, though some forget, that the Baldwin apple, the Bartlett pear, the Niagara grape, and a great multitude of analogous sorts, are descending from single seedling trees or vines, and are thus for evolutionary purposes single individuals. The distinction between such individuals and those of wild species in nature is largely psychological; we have learned to regard differences between individual apple trees, but have not attained such close acquaintance with oaks and elms. If crosses between the normally diverse individuals of a species are to be termed hybrids then the word covers all sexually differentiated organisms and is utterly useless as a means of drawing biological distinctions. Mendel deliberately disregarded the question as to which of his pea hybrids were between different species, and which between varieties merely, and for the purposes of his inquiry this was a matter of little importance. But for his followers to draw general conclusions, while ignoring all distinction between the evolutionary conditions of the organisms which they study, is a reversion to the same general woolliness of evolutionary thinking to which Mendel constituted so brilliant an exception.

The millions of species with which nature has been experimenting for millions of years seem to make it very plain that individual diversity with free interbreeding is the optimum condition for evolutionary progress, since this is what we find everywhere among natural species. It is true that the diversity masks the slow and gradual motion of the species from perception by our momentary observations, and also that the interbreeding hinders the segregation of species; but we may take the results as evidence that evolutionary progress is not impeded by wide individual variation, nor by opportunities for the progressive accumulation of new characters. Nor need we turn our backs on this interpretation of the history of organic nature because Mendel and others have given new demonstrations of the old fact that there are degrees of evolutionary divergence in which the combination of parental characters is no longer possible.

Mendel's laws are of much practical importance because they make plain to breeders of economic plants and animals that they can not do what has been attempted so frequently, make improved breeds by combining the divergent characters of close-bred varieties. The Mendelian facts are of general evolutionary interest, not because they explain descent, but because they are incompatible with the commonly accepted static theories of development which hold that evolutionary progress is due to external or environmental influences and overlook the independent self-caused motion of species. More detailed presentation of the latter view can not be undertaken here;* it must suffice for the present to have pointed out that cytology has not proved the universality of Mendel's laws as 'principles of inheritance,' nor do the laws prove that the chromosomes are the long-sought 'hereditary mechanisms.'

Heredity should be thought of as a general property of organisms, and not as the function of a special organ of the cell or of the embryo. As a phenomenon it should be associated with crystallization, on the one side, and with memory, on the other. There may be simpler properties of matter which render crystallization, heredity and memory possible, but such properties are not yet recognized in physics and chemistry, so that the terms and theories of these sciences are of little use in the discussion of evolution.

Viewed as the basis of an independent generalization the Mendelian experiments ran counter to multitudes of the most obvious and best established data of biology, and it may have been on this account that they were so long disregarded. The apparent conflict is here explained as due to erroneous theories of evolution; the recognition of spontaneous organic motion enables Mendel's facts to find a place in the evolutionary series, and renders the general inferences of de Vries, Bateson and Wilson unnecessary. Nor need the present view be thought to depreciate the importance of Mendel's laws, since such discoveries are of much greater practical value after they have found their true place among related facts than while as novelties they are permitted to obscure all the adjoining fields of investigation.

* See 'A Kinetic Theory of Evolution,' *Science*, N. S., 13: 969, June 21, 1901.

# THE PEARL FISHERIES OF CEYLON.*

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THE celebrated pearl 'oysters' of Ceylon are found mainly in certain parts of the wide shallow plateau which occupies the upper end of the Gulf of Manaar, off the northwest coast of the island and south of Adam's Bridge.

The animal (*Margaritifera vulgaris,* Schum. = *Avicula fucata,* Gould) is not a true oyster, but belongs to the family Aviculidæ, and is, therefore, more nearly related to the mussels (*Mytilus*) than to the oysters (*Ostræa*) of our seas.

The fisheries are of very great antiquity. They are referred to by various classical authors, and Pliny speaks of the pearls from Taprobane (Ceylon) as 'by far the best in the world.' Cleopatra is said to have obtained pearls from Aripu, a small village on the Gulf of Manaar, which is still the center of the pearl industry. Coming to more recent times, but still some centuries back, we have records of fisheries under the Singhalese kings of Kandy, and subsequently under the successive European rulers—the Portuguese being in possession from about 1505 to about 1655, the Dutch from that time to about 1795, and the English from the end of the eighteenth century onwards. A notable feature of these fisheries under all administrations has been their uncertainty.

The Dutch records show that there were no fisheries between 1732 and 1746, and again between 1768 and 1796. During our own time the supply failed in 1820 to 1828, in 1837 to 1854, in 1864 and several succeeding years, and finally after five successful fisheries in 1887, 1888, 1889, 1890 and 1891 there has been no return for the last decade. Many reasons, some fanciful, others with more or less basis of truth, have been given from time to time for these recurring failures of the fishery; and several investigations, such as that of Dr. Kelaart (who unfortunately died before his work was completed) in 1857 to 1859, and that of Mr. Holdsworth in 1865 to 1869, have been undertaken without much practical result so far.

In September, 1901, Mr. Chamberlain asked me to examine the records and report to him on the matter, and in the following spring I was invited by the government to go to Ceylon with a scientific assistant, and undertake any investigation into the condition of the

* Abstract of discourse before the Royal Institution of Great Britain.

banks that might be considered necessary. I arrived at Colombo in January, 1902, and as soon as a steamer could be obtained proceeded to the pearl banks. In April it was necessary to return to my university duties in Liverpool, but I was fortunate in having taken out with me as my assistant, Mr. James Hornell, who was to remain in Ceylon for at least a year longer, in order to carry out the observations and experiments we had arranged, and complete our work. This program has been carried out, and Mr. Hornell has kept me supplied with weekly reports and with specimens requiring detailed examination.

The steamship *Lady Havelock* was placed by the Ceylon government at my disposal for the work of examining into the biological conditions surrounding the pearl oyster banks; and this enabled me on two successive cruises of three or four weeks each to examine all the principal banks, and run lines of dredging and trawling and other observations across, around and between them, in order to ascertain the conditions that determine an oyster bed. Towards the end of my stay I took part in the annual inspection of the pearl banks, by means of divers, along with the retiring Inspector, Captain J. Donnan, C.M.G., and his successor, Captain Legge. During that period we lived and worked on the native barque *Rangasameeporawee,* and had daily opportunity of studying the methods of the native divers and the results they obtained.

It is evident that there are two distinct questions that may be raised—the first as to the abundance of the adult 'oysters,' and the second as to the number of pearls in the oysters, and it was the first of these rather than the frequency of the pearls that seemed to call for investigation, since the complaint has not been as to the number of pearls per adult oyster, but as to the complete disappearance of the shell-fish. I was indebted to Captain Donnan for much kind help during the inspection, when he took pains to let me see as thoroughly and satisfactorily as possible the various banks, the different kinds and ages of oysters, and the conditions under which these and their enemies exist. I wish also to record my entire satisfaction with the work done by Mr. Hornell, both while I was with him and also since. It would have been quite impossible for me to have got through the work I did in the very limited time had it not been for Mr. Hornell's skilled assistance.

Most of the pearl oyster banks or 'paars' (meaning rock or any form of hard bottom, in distinction to 'Manul,' which indicates loose or soft sand) are in depths of from five to ten fathoms and occupy the wide shallow area of nearly fifty miles in length, and extending opposite Aripu to twenty miles in breadth, which lies to the south of Adam's Bridge. On the western edge of this area there is a steep

declivity, the sea deepening within a few miles from under ten to over one hundred fathoms; while out in the center of the southern part of the Gulf of Manaar, to the west of the Chilaw Pearl Banks, depths of between one and two thousand fathoms are reached. On our two cruises in the *Lady Havelock* we made a careful examination of the ground in several places outside the banks to the westward, on the chance of finding beds of adult oysters from which possibly the spat deposited on the inshore banks might be derived. No such beds, outside the known 'paars,' were found; nor are they likely to exist. The bottom deposits in the ocean abysses to the west of Ceylon are 'globigerina ooze,' and 'green mud,' which are entirely different in nature and origin from the coarse terrigenous sand, often cemented into masses, and the various calcareous neritic deposits, such as corals and nullipores, found in the shallow water on the banks. The steepest part of the slope from ten to twenty fathoms down to about 100 fathoms or more, all along the western coast seems in most places to have a hard bottom covered with Alcyonaria, sponges, deep-sea corals and other large encrusting and dendritic organisms. Neither on this slope nor in the deep water beyond the cliff did we find any ground suitable for the pearl oyster to live upon.

Close to the top of the steep slope, about twenty miles from land, and in depths of from eight to ten fathoms, is situated the largest of the 'paars,' the celebrated Periya Paar, which has frequently figured in the inspectors' reports, has often given rise to hopes of great fisheries, and has as often caused deep disappointment to successive government officials. The Periya Paar runs for about eleven nautical miles north and south, and varies from one to two miles in breadth, and this—for a paar—large extent of ground becomes periodically covered with young oysters, which, however, almost invariably disappear before the next inspection. This paar has been called by the natives the 'mother-paar' under the impression that the young oysters that come and go in fabulous numbers migrate or are carried inwards and supply the inshore paars with their populations. During a careful investigation of the Periya Paar and its surroundings we satisfied ourselves that there is no basis of fact for this belief; and it became clear to us that the successive broods of young oysters on the Periya Paar, amounting probably within the last quarter century alone to many millions of millions of oysters, which if they had been saved would have constituted enormous fisheries, have all been overwhelmed by natural causes, due mainly to the configuration of the ground and its exposure to the southwest monsoon.

The following table shows, in brief, the history of the Periya Paar for the last twenty-four years:

Feb. 1880. Abundance of young oysters.
Mar. 1882. No oysters on the bank.
Mar. 1883. Abundance of young oysters, 6 to 9 months old.
Mar. 1884. Oysters still on bank, mixed with others of 3 months old.
Mar. 1885. Older oysters gone, and very few of the younger remaining.
Mar. 1886. No oysters on bank.
Nov. 1887. Abundance of young oysters, 2 to 3 months.
Nov. 1888. Oysters of last year gone and new lot come, 3 to 6 months.
Nov. 1889. Oysters of last year gone; a few patches 3 months old present.
Mar. 1892. No oysters on the bank.
Mar. 1893. Abundance of oysters of 6 months old.
Mar. 1894. No oysters on bank.
Mar. 1895. Ditto.
Mar. 1896. Abundance of young oysters, 3 to 6 months.
Mar. 1897. No oysters present.
Mar. 1898. Ditto.
Mar. 1899. Abundance of oysters, 3 to 6 months old.
Mar. 1900. Abundance of oysters 3 to 6 months old; none of last year's remaining.
Mar. 1901. Oysters present of 12 to 18 months of age, but not so numerous as in preceding year.
Mar. 1902. Young oysters abundant, 2 to 3 months. Only a few small patches of older oysters (2 to 2½ years) remaining.
Nov. 1902. All the oysters gone.

It is shown by the above that since 1880 the bank has been naturally restocked with young oysters at least eleven times without yielding a fishery.

The ten-fathom line skirts the western edge of the paar, and the one hundred-fathom line is not far outside it. An examination of the great slope outside is sufficient to show that the southwest monsoon running up towards the Bay of Bengal for six months in the year, must batter with full force on the exposed seaward edge of the bank and cause great disturbance of the bottom. We made a careful survey of the Periya Paar in March, 1902, and found it covered with young oysters a few months old. In my preliminary report to the government written in July, I estimated these young oysters at not less than a hundred thousand millions, and stated my belief that these were doomed to destruction, and ought to be removed at the earliest opportunity to a safer locality further inshore. Mr. Hornell was authorized by the Governor of Ceylon to carry out this recommendation, and went to the Periya Paar early in November with boats and appliances suitable for the work, but found he had arrived too late. The southwest monsoon had intervened, the bed had apparently been swept clean, and the enormous population of young oysters, which we had seen in March, and which might have been used to stock many of the smaller inshore paars, was now in all probability either buried in sand or carried down the steep declivity into the deep water outside. This experience, taken

along with what we know of the past history of the bank as revealed by the inspectors' reports, shows that whenever young oysters are found on the Periya Paar, they ought, without delay, to be dredged up in the bulk and transplanted to suitable ground in the Cheval district—the region where the most reliable paars are placed.

From this example of the Periya Paar it is clear that in considering the vicissitudes of the pearl oyster banks, we have to deal with great natural causes which can not be removed, but which may to some extent be avoided, and that consequently, it is necessary to introduce large measures of cultivation and regulation in order to increase the adult population on the grounds, give greater constancy to the supply, and remove the disappointing fluctuations in the fishery.

There are in addition, however, various minor causes of failure of the fisheries, some of which we were able to investigate. The pearl oyster has many enemies, such as star-fishes, boring sponges which destroy the shell, boring molluscs which suck out the animal, internal protozoan and vermean parasites and carnivorous fishes, all of which cause some destruction and which may conspire on occasions to ruin a bed and change the prospects of a fishery. But in connection with such zoological enemies, it is necessary to bear in mind that from the fisheries point of view their influence is not wholly evil, as some of them are closely associated with pearl production in the oyster. One enemy (a Plectognathid fish) which doubtless devours many of the oysters, at the same time receives and passes on the parasite which leads to the production of pearls in others. The loss of some individuals is in that case a toll that we very willingly pay, and no one would advocate the extermination of that particular enemy.

In fact the oyster can probably cope well enough with its animate environment if not too recklessly decimated at the fisheries, and if man will only compensate to some extent for the damage he does by giving some attention to the breeding stock and 'spat,' and by transplanting when required the growing young from unsuitable ground to known and reliable 'paars.'

Those were the main considerations that impressed me during our work on the banks, and, therefore, the leading points in the conclusions given in my preliminary report (July, 1902) to the governor of Ceylon ran as follows:

1. The oysters we met with seemed on the whole to be very healthy.

2. There is no evidence of any epidemic or of much disease of any kind.

3. A considerable number of parasites, both external and internal, both protozoan and vermean, were met with, but that is not unusual in molluscs, and we do not regard it as affecting seriously the oyster population.

4. Many of the larger oysters were reproducing actively.

5. We found large quantities of minute 'spat' in several places.

6. We also found enormous quantities of young oysters a few months old on many of the paars. On the Periya Paar the number of these probably amounted to over a hundred thousand million.

7. A very large number of these young oysters never arrive at maturity. There are several causes for this:

8. They have many natural enemies, some of which we have determined.

9. Some are smothered in sand.

10. Some grounds are much more suitable than others for feeding the young oysters, and so conducing to life and growth.

11. Probably the majority are killed by overcrowding.

12. They should therefore be thinned out and transplanted.

13. This can be easily and speedily done, on a large scale, by dredging from a steamer, at the proper time of year, when the young oysters are at the best age for transplanting.

14. Finally there is no reason for any despondency in regard to the future of the pearl oyster fisheries, if they are treated scientifically. The adult oysters are plentiful on some of the paars and seem for the most part healthy and vigorous; while young oysters in their first year, and masses of minute spat just deposited, are very abundant in many places.

To the biologist two dangers are however evident, and, paradoxical as it may seem, these are *overcrowding* and *overfishing*. But the superabundance, and the risk of depletion are at the opposite ends of the life cycle, and, therefore, both are possible at once on the same ground—and either is sufficient to cause locally and temporarily a failure of the pearl oyster fishery. What is required to obviate these two dangers ahead, and ensure more constancy in the fisheries, is careful supervision of the banks by some one who has had sufficient biological training to understand the life-problems of the animal, and who will therefore know when to carry out simple measures of farming, such as thinning and transplanting, and when to advise as to the regulation of the fisheries.

In connection with cultivation and transplantation, there are various points in structure, reproduction, life-history, growth and habits of the oyster which we had to deal with, and some of which we were able to determine on the banks, while others have been the

subject of Mr. Hornell's work since, in the little marine laboratory we established at Galle.

Although Galle is at the opposite end of the island from the pearl banks of Manaar, it is clearly the best locality in Ceylon for a marine laboratory—both for general zoology and also for working at pearl oyster problems. Little can be done on the sandy exposed shores of Manaar island or the Bight of Condatchy—the coasts opposite the pearl banks. The fisheries take place far out at sea, from ten to twenty miles off shore; and it is clear that any natural history work on the pearl banks must be done not from the shore, but, as we did, at sea from a ship during the inspections, and can not be done at all during the monsoons because of the heavy sea and useless exposed shore. At such times the necessary laboratory work supplementing the previous observations at sea can be carried out much more satisfactorily at Galle than anywhere in the Gulf of Manaar.

Turning now from the health of the oyster population on the 'paars,' to the subject of pearl formation, which is evidently an unhealthy and abnormal process, we find that in the Ceylon oyster there are several distinct causes that lead to the production of pearls. Some pearls or pearly excrescences on the interior of the shell are due to the irritation caused by boring sponges and burrowing worms. Minute grains of sand and other foreign bodies gaining access to the body inside the shell, which are popularly supposed to form the nuclei of pearls, only do so, in our experience, under exceptional circumstances. Out of the many pearls I have decalcified, only one contained in its center what was undoubtedly a grain of sand; and from Mr. Hornell's notes taken since I left Ceylon, I quote the following passage, showing that he has had a similar experience:

"February 16, 1903—*Ear-pearls.* Of two decalcified, one from the anterior ear (No. 148), proved to have a minute quartz grain (micro. preparation 25) as nucleus."

It seems probable that it is only when the shell is injured, as, for example, by the breaking off or crushing of the projecting 'ears,' thereby enabling some fine sand to gain access to the interior, that such inorganic particles supply the irritation which gives rise to pearl formation.

The majority of the pearls found free in the tissues of the body of the Ceylon oyster contain, in our experience, the more or less easily recognizable remains of Platyelmian parasites; so that the stimulation which causes eventually the formation of an 'orient' pearl is, as has been suggested by various writers in the past, due to infection by a minute lowly worm, which becomes encased and dies, thus justifying,

in a sense, Dubois' statement that—'La plus belle perle n'est donc, en définitive, que le brillant sarcophage d'un ver.'*

To Dr. Kelaart (1859) belongs the honor of having first connected the formation of pearls in the Ceylon oyster with the presence of vermean parasites. It is true that Filippi seven years before (in 1852), showed that the Trematode *Distomum duplicatum* was the cause of pearl formation in the fresh-water mussel *Anodonta,* and Küchenmeister (1856), Moebius (1857) and others extended the discovery to some of the larger pearl oysters, and to other parasites; but it is probable that Kelaart knew nothing of these papers and that he made his discovery in regard to the Ceylon oyster quite independently. He (and the Swiss zoologist, Humbert, who was with him at a pearl fishery) found "in addition to the filaria and cercaria, three other parasitical worms infesting the viscera and other parts of the pearl oyster. We both agree that these worms play an important part in the formation of pearls; and it may yet be found possible to infect oysters in other beds with these worms, and thus increase the quantity of these gems."

Thurston, in 1894, confirmed Kelaart's observation, finding in the tissues, and also in the alimentary canal, of the Ceylon oyster, 'larvæ of some Platyhelminthian (flat-worm).'

Garner (1871) associated the production of pearls both in the pearl oysters and also in our common English mussel (*Mytilus edulis*) with the presence of Distomid parasites; Giard (1897) and other French writers have made similar observations in the case of *Donax* and other Lamellibranchs; and Dubois (1901) has more recently ascribed the production of pearls in mussels on the French coast, to the presence of the larva of *Distomum margaritarum.* Jameson (1902) then followed with a more detailed account of the relations between the pearls in *Mytilus* and the Distomid larvæ, which he identifies as *Distomum* (*Brachycœlium*) *somateriæ* (Levinson). Jameson's observations were made on mussels obtained partly at Billiers (Morbihan), a locality at which Dubois had also worked, and partly at the Lancashire Sea-Fisheries Marine Laboratory at Piel in the Barrow Channel. Finally, Dubois has just published a further note† in which, referring to the causation of pearls in *Mytilus,* he says (p. 178): "En somme ce que ce dernier [Garner] avait vu en Angleterre en 1871, je l'ai retrouvé en Bretagne en 1901. Quelques jours après mon départ de Billiers, M. Lyster Jameson, de Londres, est venu dans la même localité et a confirmé le fait observé par Garner et par moi." But Jameson has done rather more than that. He has shown that it is prob-

* *Comptes Rendus,* October 14, 1901.

† *Comptes Rendus Acad. d. Sci.,* January 19, 1903.

able (his own words are 'there is hardly any doubt') that the parasite causing the pearl-formation in our common mussel (not in the Ceylon 'pearl oyster') is the larva of *Distomum somateriæ*, from the eider duck and the scoter. He also believes that the larva inhabits *Tapes* or the cockle as a first host before getting into the mussel.

We have found, as Kelaart did, that in the Ceylon pearl oyster there are several different kinds of worms commonly occurring as parasites, and we shall I think be able to show in our final report that Cestodes, Trematodes and Nematodes are all concerned in pearl formation. Unlike the case of the European mussels, however, we find so far that in Ceylon the most important cause is a larval Cestode of the Tetrarhynchus form. Mr. Hornell has traced a considerable part of the life history of this parasite, from an early free-swimming stage to a late larval condition in the file fish (*Balistes mitis*) which frequents the pearl banks and preys upon the oysters. We have not yet succeeded in finding the adult, but it will probably prove to infest the sharks or other large Elasmobranchs which devour *Balistes*.

It is only due to my excellent assistant, Mr. James Hornell, to state that our observations on pearl formation are mainly due to him. During the comparatively limited time (under three months) that I had on the banks I was mainly occupied with what seemed the more important question of the life-conditions of the oyster, in view of the frequent depletion of particular grounds.

It is important to note that these interesting pearl-formation parasites are not only widely distributed over the Manaar banks, but also on other parts of the coast of Ceylon. Mr. Hornell has found *Balistes* with its Cestode parasite both at Trincomalie and at Galle, and the sharks also occur all round the island, so that there can be no question as to the probable infection of oysters grown at these or any other suitable localities.

There is still, however, much to find out in regard to all these points, and other details affecting the life of the oyster and the prosperity of the pearl fisheries. Mr. Hornell and I are still in the middle of our investigations, and this must be regarded as only a preliminary statement of results which may have to be corrected, and I hope will be considerably extended in our final report.

It is interesting to note that the *Ceylon Government Gazette*, of December 22 last, announced a pearl fishery, to commence on February 22, during which the following banks would be fished:

The southeast Cheval Paar, estimated to have 49 million oysters.

The East Cheval Paar, with 11 millions.

The Northeast Cheval Paar, with 13 millions.

The Periya Paar Kerrai, with 8 million—making in all over 80 million oysters.

That fishery is now in progress, Mr. Hornell is attending it, and we hope that it may result not merely in a large revenue from pearls but also in considerable additions to our scientific knowledge of the oysters.

As an incident of our work in Ceylon, it was found necessary to fit up the scientific man's workshop—a small laboratory on the edge of the sea, with experimental tanks, a circulation of sea-water and facilities for microscopic and other work. For several reasons, as was mentioned above, we chose Galle at the southern end of Ceylon, and we have every reason to be satisfied with the choice. With its large bay, its rich fauna and the sheltered collecting ground of the lagoon within the coral reef, it is probably one of the best possible spots for the naturalist's work in eastern tropical seas.

In the interests of science it is to be hoped, then, that the marine laboratory at Galle will soon be established on a permanent basis with a suitable equipment. It ought, moreover, to be of sufficient size to accommodate two or three additional zoologists, such as members of the staff of the museum and of the medical college at Colombo, or scientific visitors from Europe. The work of such men would help in the investigation of the marine fauna and in the elucidation of practical problems, and the laboratory would soon become a credit and an attraction to the colony. Such an institution at Galle would be known throughout the scientific world, and would be visited by many students of science, and it might reasonably be hoped that in time it would perform for the marine biology and the fishing industries of Ceylon very much the same important functions as those fulfilled by the celebrated gardens and laboratory at Peradeniya for the botany and associated economic problems of the land.

# A COMPARISON OF LAND AND WATER PLANTS.

By Professor GEORGE JAMES PEIRCE, Ph.D.,
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THE aquatic origin of all living things is now a generally accepted conception. The arguments in its favor are: (1) morphological, based on comparative studies of the vegetative and reproductive parts; (2) biological, based on observation of the habits of plants and animals, especially at the breeding season; (3) paleontological, based on the now known fossil remains of formerly living organisms; (4) physiological, based on the absolute dependence of all living things on water. These last arguments appeal to me more strongly than any others. When we realize that all food, all the materials of which the body is constructed, and all the substances which its cells use, can enter the cells only in solution in water, we see at once how indispensable water is. When we realize besides that the form and size of the cells, and therefore of the body, depend upon the pressures within the cells which are due to the presence of aqueous solutions therein, we see how necessary water is in another way. Upon the tension of the cells depends the mechanical force which they, the tissues, and the organism, can exert. The absolute dependence of all living things upon water is one of the two most important characters which they possess. The amount of water which different cells, organs and organisms use varies greatly, but they all require some water. The ease with which different organisms, organs and cells obtain water also varies, though not necessarily in a degree corresponding with the amounts used. If we compare the conditions under which water and land plants live, we shall see some reasons for the differences in the structure and habits of these two classes.

The constantly submersed aquatic, whether fresh or salt water, is buoyed up with a very considerable force. A solid mass of plant tissue from which all air and water had been pressed would be buoyed up in water by a force from seven to eight hundred times as great as would be exerted if it were in the air. This is in accordance with Archimedes' well-known law in physics—a body in a fluid is buoyed up with a force equal to the weight of the volume of fluid which it displaces. Any part of a land plant, therefore, which rises into the air is supported with say only one seven hundredth of the force which supports the submersed aquatic. This difference is met by the land plant in two ways. It develops tissues which mechanically support it, which carry that part

of its weight which the air can not carry; and it so constructs certain parts, for instance the leaves, of nearly all but the pines and their allies, that their form is best fitted for floating. The leaves are the organs in which most food is made. Their efficiency depends upon the amount of light which they can absorb, and they will evidently absorb most light if they are flat and placed at right angles to the rays as they come from the sun. This may be the main reason for the expanded form of the leaves, and it is the only reason which has been proved by experiment. But it is evident that a leaf is buoyed up more strongly and, therefore, requires less mechanical support if it is flat and more or less horizontal than if it were vertical or if it were cylindrical or cubical. Comparing weight for weight, we find more mechanical tissue in the pine-needle than in the flat leaf. And we find no such mechanical tissues even in the largest and longest submersed aquatics, some of which are as long as trees are tall.

The amount of mechanically strengthening tissue in a part or a plant has been proved by experiment to depend upon the amount of mechanical strain to which it is exposed. Garden plants which ordinarily carry the weight of their branches will be mechanically much weaker if supported on trellises. Conversely climbers and prostrate plants, if subjected to mechanical pull, will develop strengthening tissues which they ordinarily do not form. In these cases, the so-called inherited tendency to form or not to form mechanically strengthening tissues is so promptly overcome in the individuals experimented upon as to suggest some doubt whether there is such a tendency at all, whether the structure and behavior of living things is not more due to the influence of their surroundings than to inheritance.

We may conclude, then, that the presence in erect land plants of mechanically supporting tissues which are never found in submersed aquatics is not mere coincidence. The difference in the mechanical tissues of these plants is due, not to the differences in their places in any scheme of classification or to their degree of evolution, but to the differences in the buoyancy of air and water. Aquatic plants do develop mechanical tissues, but they resist the pullings, bendings and blunt blows which the waves give. These tissues can not support much weight.

The strength of the submersed aquatic will vary greatly according as it is a floating or an attached organism. All submersed aquatics which are unattached are mechanically weak and they are usually small, whereas those which are attached must develop a certain amount of mechanical strength to resist the tugging of the free parts against the holdfasts. Compare, for instance, *Spirogyra* and fresh-water *Cladophora,* plants of somewhat similar size, structure and situation. A *Cladophora* filament will break only under a much stronger pull than

a *Spirogyra* filament of the same size and general structure growing in the same pool. *Cladophora* grows attached, *Spirogyra* is free. Compare *Nereocystis* and *Macrocystis*, the great kelps of the Pacific, with the *Sargassum* of the Atlantic. *Sargassum* begins life as an attached plant but is mechanically weak, is broken away and is for most of its life free. Our Pacific kelps are always attached and are tremendously tough. The comparison is not fair, however, for *Sargassum* is smaller than our giant kelps.

The attached plants between the tide-marks are among the most interesting as to mechanical strength. The rock weeds (*Fucus*), the *Irideas*, the *Gigartinas*, etc., of our Pacific shore withstand a tremendous amount of pulling and buffeting and are very hard to pull, though comparatively easy to tear, to pieces. These and other thinner and more delicate plants, *e. g.*, the *Ulvas*, *Porphyras*, etc., escape destruction by their extreme pliancy rather than by toughness.

The most striking example of mechanical strength displayed by any plant living between the tide-marks is furnished by the sea palm (*Postelsia*), which is peculiar to the Pacific coast. This plant grows to a height of twelve to eighteen inches. The erect and smooth tapering trunk rises from the tangled mass of holdfasts attaching it to the flat or shelving ledge. The leaves, often over half as long as the trunk, narrow and corrugated, spring from its top. The trunk is like that of an erect land plant in being able to support a considerable weight applied vertically. The sea palm resembles in carrying power the land plant which gave it its name, but its remarkable strength is shown by its living where almost nothing else can, where the constantly beating surf is too much even for barnacles unless they take hold in some crevice. The spores must germinate very rapidly in the short times of comparative quiet, taking fast hold of the rock, for in most places where I have seen the sea palm growing, the waves were constantly in motion, and usually so violent, even at low water, that a man would be carried off his feet almost instantly. The sea palm bows before a breaker, bends away from it, resists its downward crushing force, holds on and holds together in spite of the shoreward thrust and seaward pull, thrives only where the sea is roughest, is the only plant where it grows every part of which has not fast hold of the rock.

Turning from the relative buoyancy of air and water and the effect of this difference in the supporting tissues of land and water plants, we may examine the relative ease with which land and water plants obtain their food-materials. The means by which any organism takes food or food materials into its living cells are simple though not generally enough understood. Only when the aqueous solution in the cell, permeating all its parts including the wall, is in contact with

an aqueous solution outside the cell, can there be any absorption. The submersed aquatic has many or all of its cells in direct contact with the water. The land plant has only those cells which touch, or are in, the soil which are regularly in direct contact with water. Except those plants living in swamp or marsh, and except immediately after heavy rain, land plants are able to obtain only those thin films of water held on the surfaces of the soil particles. To reach these films, to bring the solution within the cells into contact with the water (also a solution) on the soil particles, land plants develop hairs—the rhizoids of the lower forms, the root-hairs of the higher. An aquatic composed of a chain or of a film of cells has all its cells directly in contact with the water, which holds in solution oxygen, carbon dioxide, and those mineral salts which constitute its food materials. An aquatic composed of a mass of cells, on the other hand, has only some cells which are able directly to absorb food materials from the water, those cells on the surface. The surface cells constitute the absorbing organ. Under these are other cells, containing chlorophyll, which manufacture the absorbed food materials into foods. If the plant is small, there may be besides only those cells which are used for storing the manufactured product and those concerned with reproduction. If the plant is larger, like the rock weeds and kelps, there must be in addition a system of cells for conducting the foods from the cells manufacturing them to others needing them. In all aquatics, even the largest, unless some are land plants retaining the structures characteristic of land plants even after becoming aquatic, there is only this one system of conducting tissues, the one which distributes food.

As we pass from the submersed aquatics to those only periodically submersed, from these to plants living prostrate on the ground, like most liverworts, and from these to erect plants, we see progressive changes in absorbing and conducting systems. The plants living between the tide-marks, for example the rock weeds and devil's apron (*Laminaria*), possess a conducting system similar to the submersed kelps, but the absorbing system is reduced in extent to prevent the plant from losing water by evaporation while exposed at low tide. In these plants there is need of two sets of qualities, those adapted to life under water, those fitted to life in the air—essentially, enough cells for absorbing water, and enough cells so placed and of such composition as to keep evaporation within safe limits.

The prostrate land plants, for example the liverworts, possess tissues similar to the small though massive algæ living between the tide-marks—an absorbing system and a protective system. But as, for most of the time, the prostrate land plant can absorb water only from the soil underneath it, and lose water by evaporation only from its upper surface, the absorbing and protective systems are

separated, the food-manufacturing tissue lying between the other two. These prostrate plants are all so small that no conducting system is needed.

So soon as a plant turns up into the larger and unoccupied space above the soil, the part which grows up cuts itself off from a direct supply of water and mineral food materials and exposes itself to greater loss by evaporation. The absorbing system of the part still in contact with the soil must be extended, the part above must be covered with material less permeable to water, and a conducting system which will supply the part above with water, which can come only from below, must develop. This we find in the erect mosses, and also in these cells which mechanically support the parts the weight of which is not wholly or directly carried by air and soil. The larger mosses, *Polytrichum* for instance, show these different tissues.

When a plant assumes the erect posture, its structure must correspond with its changed habit. The anatomical changes in man's body, which supposedly took place when he assumed the erect posture, have been explained by zoologists. Similarly there are changes in the bodies of plants which take on the erect habit of growth. These changes enable them to conform to the new relations and degrees of mechanical strains, the different relations to absorption and loss of water, the different relations to light, etc. The simpler, larger, erect plants, for instance the grasses, have worked out the relations of absorbing, protecting, food manufacturing, conducting, and mechanically supporting systems in very definite fashion. In these plants, absorbing and food-manufacturing systems are remote from each other, connected, however, by conducting tissues which carry the mineral salts and water needed for food manufacture, plus the amount of water which must inevitably be lost by evaporation, an amount constantly varying everywhere, but differing greatly according to situation, climate, etc. In these plants there must be the other conducting system, the one for distributing the food made in the leaves to all the living cells in other parts. Here we encounter, as in the ferns and their allies, which might equally well have been selected as illustrating these points, the double conducting system. The food-distributing system is found in all larger plants in which there are other living cells than those engaged in food manufacture. This is the primitive conducting system, the one first needed, as our consideration of the larger aquatics showed. Only when absorbing and food-manufacturing tissues are remote from each other is another conducting system needed and developed, and the dimensions of this correspond with the volume of water to be carried to supply food materials and to make good the loss by evaporation.

In the ferns and their allies, and in the grasses, the tissues mechanically supporting the parts above ground are combined into what may be called an external skeleton. This is distinct from the conducting tissues. It forms a cylinder close under the epidermis and enclosing the conducting and storing tissues. Each strand of conducting tissue may also be inclosed in a strengthening cylinder. This kind of skeleton is strong for the weight and amount of material in it, but it has the serious disadvantage of limiting the size of the organ or organism. The lobster and crab can continue to grow only by splitting the external skeleton. They shed this periodically, forming a new and larger one. Till this is formed they are weak and defenseless. If an erect plant were to split its external skeleton it would be too weak to stand. The limit which it sets to the size of the plant, rather than the difficulty of branching which is sometimes alleged as the disadvantage, is the serious defect in an external skeleton.

The grasses show an approach to an internal skeleton in that the greater part of the strength of the stem is due to the cylinders of supporting tissue in which the strands of conducting tissue are enclosed. But if the whole plant were to continue to grow, the cylinders in which the conducting tissues are enclosed would have to increase in diameter to allow an increase in the conducting tissues and this can not be done without splitting the strengthening cylinders and thereby greatly weakening the whole plant.

In the pines (using the word broadly) support and the conduction of liquids are accomplished by the same tissues, the same cells. These are the lowest plants in which an internal skeleton, if I may call it so, is found. Such a skeleton sets no limit to growth. It can be added to year by year as there is need of increased strength, and at the same time increased conducting tissue is formed. But conduction and mechanical support can not both be attained with the utmost efficiency and economy of material in cells which must serve both purposes. The diameter of the conducting elements must be limited lest they be weak, they must be comparatively short for the same reason, there can be no continuous tubes through which liquids can be rapidly transported. To ensure the requisite mechanical strength to the whole plant, the walls of the conducting cells must be thicker than would otherwise be necessary.

In the highest flowering plants, the dicotyledons, conducting and mechanically supporting tissues are combined in the same strands, but the same cells do not serve both purposes. In these plants, conducting and strengthening cells are side by side, they increase in number according to the needs of the plant, the conducting cells most rapidly when most needed—as in the early spring—the strengthening cells later, when the increasing weight of the growing parts

makes increased support necessary. In this combination of conducting and strengthening tissues, with the distribution of the two functions among different cells, the highest efficiency with the greatest economy of material is possible. There is no limit to which the plant can increase in size, provided only it preserve, from year to year, a layer of reproductive cells (the cambium) from which new cells developing into new conducting and strengthening elements may be formed.

In comparing the conditions under which water and land plants live this must be added. In the water, conditions change slowly and in regularly recurring periods. On land they change not only in regularly recurring periods but also frequently and suddenly. Submersed aquatics fall into a smaller number of species than do the plants living between the tide-marks. These again are numbered in fewer species than are land plants. The vertical distribution of aquatics is limited by the light to a few feet; the vertical distribution of land plants is limited by the temperature to a few thousand feet. Within this greater vertical space there is far greater diversity of conditions than in the shallow layer of water in which plants can live. This greater diversity of environment has been the cause of the greater diversity among land plants. But land and water plants, were they not sensitive to all the influences which combined make their environments, and had they not reacted to these influences, would never have attained the diversity which they now possess. The dependence of all living things upon water, and their power of reacting to all the influences of their environment to which they are sensitive, are the most striking phenomena displayed by animals and plants.

# THE PRESERVATION OF WILD FLOWERS.

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THE fact that several of our delicate and most beautiful wild flowers are fast disappearing from places where they were once found has led to an effort to prevent the complete extermination of certain species and the increasing scarcity of other plants. The plants so endangered differ in different localities. The endeavor to protect particular ones has therefore local modifications, but the basis of the movement, the desire to prevent wasteful destruction of plant life, is the same in all sections of the country.

A national society, known as 'The Wild Flower Preservation Society of America,' has been organized, aiming to do for the native plants what the Audubon Society has so well done for the birds. Its methods of work are similar to those of the bird society. In its official organ, *The Plant World,* has been published during the past year a series of articles on the general subject of plant preservation with the addition of specific suggestions regarding the flowers about New York city. Reprints of these articles may be obtained upon application to the secretary of the society, C. L. Pollard, 1854 Fifth Street, Washington, D. C. A number of persons in New England who take keen interest in wild flowers have united to form a 'Society for the Protection of Native Plants.' The object of this society is to try to do something to check the wholesale destruction to which our native plants are exposed. Brief appeals, to the general public, to children and to nature study teachers have beeen issued and widely distributed in the form of leaflets, which can be obtained of Miss Maria Carter, Boston Society of Natural History. In the state of Connecticut laws have been passed which protect the Hartford fern, and governing boards of various metropolitan reservations of field and woodland have made restrictions regarding the picking of their flora.

The problem presented to the various organizations interested in plant preservation is how depredations may be checked without seriously restricting the freedom or enjoyment of the nature lover. It is desired to set at work such factors as will arouse a healthy public sentiment against indiscriminate and thoughtless flower picking.

The work is much more difficult than that which was before the Audubon Society, and the right public sentiment can not be created in the same manner. Many of the strongest reasons given for bird

protection are wanting in an appeal for the plants. Birds, high in the scale of animal life, with power to feel pain and pleasure, with food-seeking, home-making and young-protecting instincts, demand, as fellow creatures, freedom from cruelty. Efforts were first made to protect them as individuals, while the prevention of the destruction of species was a secondary consideration. Through the agricultural department of our government, knowledge of the great economic value of birds was disseminated, and this was a most effective means of in-

GOLDEN-ROD (*Solidago serotina*).

suring their protection. Through the same department people learned of the vast value of our trees to preserve which a public sentiment was created. Laws were then passed for their protection, and we now have a distinct forestry policy.

To most persons our wild plants are only things of beauty, common property to be admired or destroyed at will and, therefore, can not be preserved by the same petitions as were made in behalf of the birds. The appeal for the plants is much more difficult and must be at first

not a thoughtfulness for the plant, less it degenerate into an unhealthy sentiment, but a request that consideration be given to the rights of other people, that common property be protected for com-

TWINFLOWER (*Linnæa borealis*).

mon enjoyment. Efforts to create reforms through calling upon higher altruistic motives require a long time for their process of evolu-

GREAT LAUREL (*Rhododendron maximum*).

tion, and demand most strenuous work in order that the 'influence of the enlightened few' may be felt by the 'unenlightened many.' Permanent reform is best assured by positive rather than negative means,

and this particular one can be easily, though slowly, accomplished through nature study.

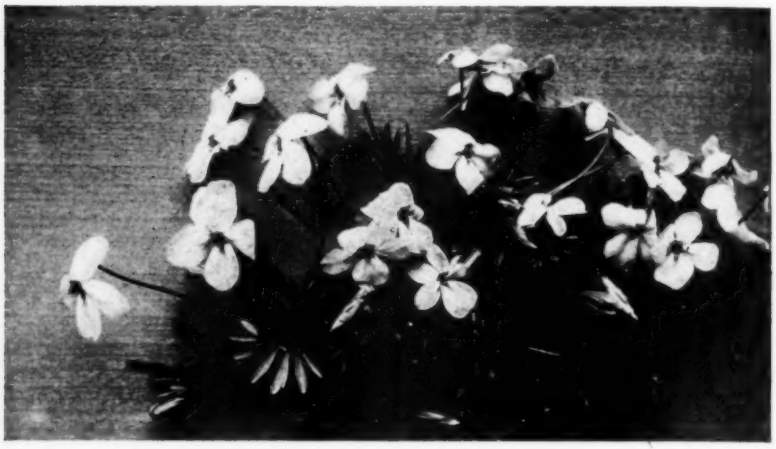
The increasing interest in the study of nature and the publication of numerous illustrated popular books on the subject have been much feared by the friends of the wild flowers, who feel that wanton destruction will follow in the path of the enthusiastic young student. This fear has been somewhat justified in towns and cities where, in their eagerness to get specimens for the class, the thoughtless pupils have robbed the parks and gardens. Perhaps, too, in the country, the nature study program has been the

ASTER (*A. spectabilis*).

SABBATIA (*S. stellaris*).

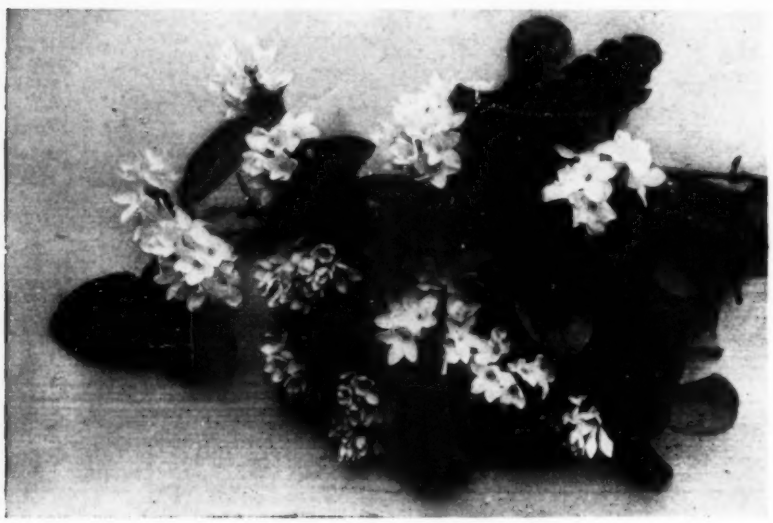
means of reducing the numbers of our most attractive wild flowers. This was a natural result of the first step in a movement which will develop into a more carefully directed study. The popular teaching of ornithology in America has advanced farther than botany. In its early days collecting 'sets of eggs' and skins of birds were prominent features of the work and the extinction of the great auk was one of the results. But now, partly through nature study and partly through the influence of the Audubon Society, studying the habits of birds, naming them without a gun, photographing eggs in the nest and birds in the bush are the most popular aspects of the study.

The gathering of plants to be used in schools as specimens for class instruction can be obviated by school authorities arranging to purchase such supplies from botanic gardens or nurseries where they have been



BIRD-FOOT VIOLET (*Viola pedata*).

raised in large numbers for the purpose. Such an arrangement has been made between a few teachers of botany in Boston, and the



PLYMOUTH MAYFLOWER, TRAILING ARBUTUS (*Epigæa repens*).

directors of the Bussey Institute of Harvard University. Well might a portion of city parks and public gardens be devoted to the raising of such plants as are in demand for botanical instruction. The farmer's

boy or girl, having at his disposal various kinds of land and being able to gain intimate knowledge of the conditions best suited to the different wild flowers which would not flourish in a city park, can experiment with their cultivation, and in time find the raising of native plants a useful and fascinating employment. The instilling of a love of flowers will help to protect them, but this must be united with scientific knowledge of their structure and relation to their environment in order that the necessity for restricting the manner in which they are gathered and the number that are collected will be evident.

The epigæa perhaps has suffered more from inroads upon it than any other New England plant. Its sweet odor and delicate beauty

MOUNTAIN LAUREL (*Kalmia latifolia*).

were in themselves attractive. Its connection with the Plymouth settlement created for it a patriotic sentiment which unfortunately was not united with a knowledge of the office of its underground root-stock and its slow manner of growth. Bryant's poem drew to the fringed gentian the attention of those who never knew before of its intrinsic beauty and interesting botanical structure. It is now being gathered for flower markets and becoming scarcer in meadows.

The epigæa, the gentian and other fast disappearing flowers, though difficult of cultivation, should be choicely guarded in wild flower reservations, which should be to the plants of America what the large country estates are to those of England. The Sharon Biological

PURPLE FRINGED-ORCHIS (*Habenaria psycodes*).

to destroy the plants needlessly, but will unite themselves with the 'enlightened few' until they become the enlightened many. Then the gentian, the sabbatia, the epigæa, the orchids and other delicate plants, ill fitted to struggle for existence, but not necessarily unworthy to survive, will be protected and mutual aid will become a factor in their evolution.

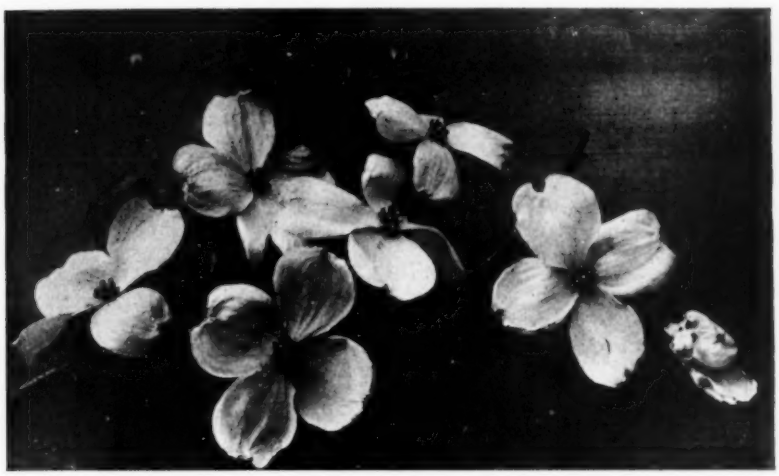
Plant preservation depends partly upon the natural adaptation of plants to their environment and partly upon the attitude of people toward them. The very absence of beauty in some plants

Observatory controls three hundred acres of land in Massachusetts which serves as a preserve for native plants and animals. All the deciduous trees of the state and also the native flowering plants are now growing there under protection. As people become more and more devoted to nature study; when they see how much more beautiful the plants are in their haunts than in a wilted bouquet; when they gain more knowledge of botany and know the plants intimately, learning in what ways they struggle for existence; they will not need to be asked not

SWAMP ROSE-MALLOW (*Hibiscus Moscheutos*).

renders them unlikely to be destroyed by too much picking, while the strikingly beautiful ones fall prey to thoughtless collectors. Others, on account of their protective coloration, escape the notice of wild flower gatherers or browsing cattle. The disagreeable odor of the skunk cabbage, the bitter taste of the crowfoots, the poisonous properties of various members of the parsley and nightshade families, and the stinging glands of the nettles prevent animals from repeating unpleasant experiences with them.

The power to produce, through a long season, many flowers, bearing many seeds, well adapted for dissemination and germination, under ordinary conditions, is the height of plant differentiation for preservation of species. A consideration of some New England wild



FLOWERING DOGWOOD (*Cornus florida*).

flowers will serve as specific illustrations of the way in which plants are self protected and the reasons why they require other aid in order that preservation may be insured.

In the early days of April the bloodroot pushes itself through the ground, each flower-bud rolled in a green leaf. The leaf unrolls somewhat; the flower pushes itself through it up into the air. The delicate calyx drops off and the corolla of pure white petals spreads itself out surrounding a cluster of golden yellow stamens, in the center of which is the pistil. After a few days the stamens wither up, the petals drop off and the pistil, if fertilized, remains, growing larger and larger until the ovules within it are matured. Then the work of the plant, along the line of perpetuation of its kind, is over for a year. The unfolded leaves expand more and more on their lengthened petioles and spread themselves out into the light and air. They then continue

to act as organs of great activity in the vegetative work of the plant. Through them carbon dioxide and oxygen are taken in from the air and united, in the green cells, with water and nitrogenous matter absorbed from the soil by the root hairs. The carbon dioxide and water unite to form carbohydrates such a starch and sugar, and oxygen which is given off as a waste product. The carbohydrates and other food products, proteids manufactured in the leaves, are transported to regions of growth, such as buds, or places of storage, like underground stems. Before being transported to growing points, the insoluble products are digested or changed to soluble forms, starch being changed to sugar and then transformed into various plant tissues. If carried to storage regions they are first converted back into insoluble forms,

SHOWY LADY'S SLIPPER (*Cypripedium spectabile*).

such as starch, and then stored up to supply energy for the rapid development of the next spring.

Picking the flowers of the bloodroot destroys the only possible chance of those particular flowers producing seed which may be able to survive and reproduce their kind. Destroying the leaves or the root-stock interferes with subsequent growth of the plant.

Herbaceous perennials, that is soft-stemmed plants which live on and produce flowers season after season, die down to the ground each fall and in the spring send forth shoots from the buds which are just under the surface. Those which blossom earliest have the largest

underground storehouses. The solomon's seal, ginseng, anemone, violet, bellwort, trillium and iris have underground rootstocks which provide energy for rapid development in the spring. The adder's tongue and other lilies, the claytonia or spring beauty, and the jack-in-the-pulpit have bulbs or corms deep down in the ground which serve as storehouses for plant food. They send up in the spring a few comparatively large leaves and a single scape of flowers which can be picked without doing much damage to the plant itself. The jack-in-the-pulpit, however, grows in moist soil and is easily uprooted. The mayflower (epigæa), and the twin-flower (linnæa) both have slender, rather woody creeping rootstocks which are frequently torn up when the blossoms are broken off rather than cut off.

The late blooming perennials suffer less by picking than those plants which blossom earlier, for their vegetative work for the season is nearly completed when they become attractive and subject to injury. The woody perennials, shrubs and trees, form buds in the axils of their leaves and at tips of branches. The buds increase in size during the summer and the next spring become swollen as the sap from the stem rises in them. Then they burst open and develop into new branches bearing leaves and flowers. If the twigs are broken off the growth of several years and also the buds, promises of new branches, are destroyed. The rhododendron, magnolia, mountain laurel, flowering dogwood and other attractive early blooming shrubs suffer in this way. The gathering of mountain laurel for winter decorations destroys quantities of buds which would have developed into beautiful clusters of blossoms in the early summer. Careful cutting or pruning of a shrub or tree is nevertheless advantageous to it, checking an over exertion on the part of the plant, which is necessary to flower production, and thereby strengthening the parts which remain.

Annuals are herbaceous plants which live but one year, dying after the maturing of the seed. Their only means of perpetuating their race is through the production of seed. Wholesale plucking of their blossoms will, therefore, lead to their extermination. The fringed gentian, and the pink sabbatia are among these plants. They are very difficult to transplant and local in distribution. The painted cup, known in the west by the better name of painter's brush, is also an annual, and exhibits a sign of weakness in parasiticism of its roots. These plants call for special protection. Careful cutting of few blossoms from the portions of a plant where they are thickest is often a benefit to the flowers which remain, giving them additional energy for the production of fruit which is more exhausting to the plant than production of flowers.

Notwithstanding the inroads that are made upon violets they thrive and increase in numbers. One reason for this is that they have hidden underground flowers which do not open, but in which self-pollination is effected and seed produced, giving the violet an extra means of reproducing its kind. The fringed polygala is also provided with these hidden flowers. Many of the so-called weeds, plants which have been accidentally introduced into this country, are so well fitted for the struggle for existence that they have successfully combated against unnatural environment and have increased enormously in numbers and geographical distribution. Many of these, as the daisy (white weed), chickory, dandelion and the thistle, as well as the native golden rods and asters, are members of the compositæ family. This group is represented by over 10,000 species, comprising one tenth of all the seed plants, each represented by many individuals of a wide range. This family of plants is the most highly differentiated. Numbers of small flowers are arranged in compact heads or clusters, presenting a complete organization in which there is a division of labor among the members of a head. They present various contrivances for cross-pollination and various adaptations of the calyx into agents for seed dissemination.

In the early summer the fields are white with daisies, which later are replaced by the golden rods. Their

> Midas touch hath turned the land to gold
> For us to have and hold.

Quantities of golden rod, as well as daisies, asters, golden-ragwort, chicory, fleabane and rudbeckia can be gathered without causing any serious reduction in their numbers. The desire to possess armfuls of flowers is thereby gratified, as is also the farmer who counts these plants as pests.

# AN UNTILLED FIELD IN AMERICAN AGRICULTURAL EDUCATION.

By KENYON L. BUTTERFIELD.

AGRICULTURAL education in this country has thus far been an attempt to apply a knowledge of the laws of the so-called 'natural' sciences to the practical operations of the farm. Comparatively little attention has been paid to the application of the principles of the 'social' sciences to the life of the farmer. All this is partly explained by the fact that the natural sciences were fairly well developed when the needs of the farmer called the scientist to work with and for the man behind the plow—when a vanishing soil fertility summoned the chemist to the service of the grain grower, when the improvement of breeds of stock and races of plants began to appeal to the biologist. Moreover, these practical applications of the physical and biological sciences are, and always will be, a fundamental necessity in the agricultural question.

But in the farm problem we cannot afford to ignore the economic and sociological phases. While it may be true that the practical success of the individual farmer depends largely upon his business sense and his technical education, it is folly to hope that the success of agriculture as an industry and the influence of farmers as a class can be based solely upon the ability of each farmer to raise a big crop and to sell it to advantage. General intelligence, appreciation of the trend of economic and social forces, capacity to cooperate, ability to voice his needs and his rights, are just as vital acquirements for the farmer as knowing how to make two blades of grass grow where but one grew before. It finally comes to this, that the American farmer is obliged to study the questions that confront him as a member of the industrial order and as a factor in the social and political life of the nation, with as much zeal and understanding as he is expected to show in the study of those natural laws governing the soil and the crops and the animals that he owns.

In this connection it is significant to note that farmers themselves are already quite as interested in the social problems of their particular calling and in the general economic and political questions of the day, as they are in science applied to their business of tilling the soil. Not necessarily that they minimize the latter, but they seem instinctively to recognize that social forces may work them ill or work them good according to the direction and power of those forces. This statement

is illustrated by the fact that the aims, purposes, labors and discussions of the great farmers' organizations like the Grange are social in character, having to do with questions that are political, economic, sociological.

When, however, we turn to those public educational agencies that are intended to assist in the solution of the farm problem, we discover that they are giving slight attention to the social side of the question. An examination of the catalogues of the agricultural colleges, whether separate institutions or colleges of state universities, reveals the fact that, beyond elementary work in economics, in civics, and occasionally in sociology, little opportunity is given students to study the farm question from its social standpoint. With a few exceptions, these institutions offer no courses whatever in rural social problems, and even in these exceptional cases the work offered is hardly commensurate with the importance of the subject. Nearly all our other colleges and universities are subject to the same comment. The average student of problems in economics and sociology and education gains no conception whatever of the importance and character of the rural phases of our industrial and social life.

It may be urged in explanation of this state of affairs that the liberal study of the social sciences, and especially any large attention to the practical problems of economics and sociology, in our colleges and universities is a comparatively recent thing. This is true and is a good excuse. But it does not offer a reason why the social phases of agriculture should be longer neglected. The purpose of this article is less to criticize than to describe a situation and to urge the timeliness of the large development, in the near future, of rural social science.

At the outset the queries may arise, What is meant by rural social science? And, What is there to be investigated and taught under such a head? The answer to the first query has already been intimated. Rural social science is the application of the principles of the social sciences, especially of economics and sociology, to the problems that confront the American farmer. The reply to the second query is not designed as an outline of all the courses that may be offered, but merely as a concrete illustration of work that could be followed by investigators and teachers, and by them indefinitely expanded.

Taking first those subjects that have an economic bearing, we may suggest agricultural geography: the relation of soil and climate to agriculture, agricultural resources, the natural and actual distribution of crop-growing, relation of science to agriculture, etc.—The farmer's market: including, besides a general discussion of the subject, a consideration of the special features of the local market, the domestic market and the foreign market. Also, a brief discussion of special influences affecting the farmer's market, such as the tariff, export duties, bounties, dealings in 'futures,' crises, the development of manu-

facturing, etc.—Questions like the relation of transportation, of industrial concentration, and of taxation, to agriculture.—Business cooperation among farmers.—Exchange facilities in rural districts.—Tenant farming.—Large *vs.* small farming.—Machinery and agriculture.—History of the farming industry.

Considering now themes that are more purely sociological, we may name rural education, including first, the rural schools proper and second, agricultural education especially. Under the latter head could be discussed nature-study teaching in rural schools, agricultural schools and colleges, experiment station work, agricultural fairs, farmers' institutes.—Rural religious institutions.—Farmers' organizations: the Grange, farmers' clubs, farmers' alliances.—Rural communication: wagon roads, trolley lines, telephones, rural mail delivery.—Degeneracy, pauperism, intemperance, crime, in rural life.—Social life in the country.—Arts and crafts in rural communities.—Rural social psychology.—Social history of agriculture.

These lists are purely suggestive and by no means complete. There are also subjects that have a political bearing, such as local government in the country, and primary reform in rural communities, which perhaps ought not to be omitted. So too, various phases of home life and of art might be touched upon. The subjects suggested and others like them could be conveniently grouped into from two to a dozen courses, as circumstances might require.

What classes of people may be expected to welcome and profit by instruction of this character? (1) The farmers themselves. Assuming that our agricultural colleges are designed, among other functions, to train men and women to become influential farmers, no argument is necessary to show how studies in rural social science may help qualify these students for genuine leadership of their class of toilers. On the other hand, it may be remarked that no subjects will better lend themselves to college extension work than those named above. Lectures and lecture courses for granges, farmers' clubs, farmers' institutes, etc., on such themes would arouse the greatest interest. Correspondence and home study courses along these lines would be fully as popular as those treating of soils and crops. (2) Agricultural educators. The soil physicist or the agricultural chemist will not be a less valuable specialist in his own line, and he certainly will be a more useful member of the faculty of an agricultural college, if he has an appreciative knowledge of the farmer's social and economic status. This is even more true of men called to administer agricultural education in any of its phases. (3) Rural school administrators and the more progressive rural teachers. The country school can never become truly a social and intellectual center of the community until the rural educators understand the social environment of the farmer. (4) Country clergymen. The vision of a social service church in the country will remain but a

dream unless, added to the possession of a heart for such work, the clergyman knows the farm problem sufficiently to appreciate the broader phases of the industrial and social life of his people. (5) Editors of farm papers, and of the so-called 'country' papers. Probably the editors of the better class of agricultural papers are less in need of instruction such as that suggested than is almost any one else. Yet the same arguments that now lead many young men aspiring to this class of journalism to regard a course in scientific agriculture as a vestibule to their work, may well be used in urging a study of rural social science, especially at a time when social and economic problems are pressing upon the farmer. As for the country papers, the work of purveying local gossip and stirring the party kettle too often obscures the tremendous possibilities for a high class service to the rural community which such papers may render. No men, in the agricultural states at least, have more real influence in their community than the trained, clean, manly, country editors—and there is a multitude of such men. If as a class they possessed also a wider appreciation of the farmer's industrial difficulties and needs, hardly any one could give better service to the solution of the farm problem than could they. (6) Everybody else! That is to say, the agricultural question is big enough and important enough to be understood by educated people. The farmers are half our people. Farming is the largest single industrial interest in the country. The capital invested in agriculture is four fifths the capital invested in manufacturing and railway transportation combined. Whether an individual has a special interest in business, in economics, in education, or in religious institutions, he ought to know the place of the farm and the farmer in that question. No one can have a full appreciation of the social and industrial life of the American people who is ignorant of the agricultural status.

The natural place to begin work in rural social science is the agricultural college. Future farmers and teachers of farmers are supposed to be there. The subjects embraced are as important in solving the farm problem as are biology, physics or chemistry. No skilled farmer or leader of farmers should be without some reasonably correct notions of the principles that determine the position of agriculture in the industrial world. A brief study of the elements of political economy, of sociology, of civics, is not enough; no more than the study of the elements of botany, of chemistry and of zoology is enough. The specific problems of the farmer that are economic need elucidation alongside the study of soils and crops, of plant- and stock-breeding. And these economic topics should be thoroughly treated by men trained in social science, and not incidentally by men whose chief interest is technical agriculture.

The normal schools may well discuss the propriety of adding one or

two courses which bear on the social and economic situation of the rural classes. While these schools do not now send out many teachers into rural schools, they may do so under the system of centralized schools; and in any event they furnish rural school administrators, as well as instructors of rural teachers. There seems to be a growing sentiment which demands of the school and of the teacher a closer touch with life as it is actually lived. How can rural teachers learn to appreciate the social function of the rural school, except they be taught?

Nor is there any reason why the theological seminaries, or at least the institutions that prepare the men who become country clergymen, should not cover some of the subjects suggested. If the ambition of some people to see the country church a social and intellectual center is to be realized, the minister must know the rural problem broadly. The same arguments that impel the city pastor to become somewhat familiar with the economic, social and civic questions of the day hold with equal force when applied to the necessary preparation for the rural ministry.

The universities may be called upon to train teachers and investigators in rural social science for service in agricultural colleges, normal schools and theological seminaries. Moreover, there is no good reason why any college or university graduate should not know more than he does about the farm problem. There can be little doubt that the interest in the farm question is very rapidly growing, and that the universities will be but meeting a demand if they begin very soon to offer courses in rural social science.

The arguments for rural social science rest, let us observe, not only upon its direct value to the farmers themselves, but upon its necessity as a basis for that intelligent social service which preacher, teacher and editor may render the farming class. It is an essential underlying condition for the successful federation of rural social forces. Indeed it should in some degree be a part of the equipment of every educated person.

It may not be out of place to add, in conclusion, that instruction in rural social problems should be placed in the hands of men who are thoroughly trained in social science as well as accurate, experienced and sympathetic observers of rural conditions. It would be mischievous indeed if in the desire to be progressive any educational institution should offer courses in rural social science which gave superficial or erroneous ideas about the scientific principles involved, or which encouraged in any degree whatever the notion that the farmer's business and welfare are not vitally and forever bound up with the business and welfare of all other classes.

# THE STORY OF ENGLISH EDUCATION.

By J. E. G. DE MONTMORENCY, B.A., LL.B. (Cantab.),
BARRISTER-AT-LAW.

THE history of education in England is a subject of profound interest and of singular importance; for it is intimately associated with all the great crises of the national life, and exhibits, as no other subject can, the effects of the interplay of religion, learning and politics upon the sociological development of a great people. The subject is, moreover, one that belongs to all the daughter-nations of England, whether, like Canada, they are still, to use a simile from Roman law, within the English *manus,* or whether, like the United States, they have become *sui juris.* For it is necessary to go back far in time if we would trace with honesty the obscure streams of thought, learning and tendency that are responsible for the great systems of education in force in the various parts of the English-speaking world to-day. We have indeed to go back to times which are the common property of that world, and delve among the records of fifteen hundred years of strife and effort if we would understand the meaning and the direction of modern education as conceived by the Anglo-Saxon race. It is well sometimes to dwell, if only for a moment, on the permanence, the persistence, the soundness of the social forces that through a millennium and a half have emanated and still emanate from Britain. Fifteen hundred years almost exactly measured the period of the great Roman race from Romulus the first king to Romulus the last emperor. The Anglo-Saxon race at the end of a similar period shows little sign of exhaustion. It has, as we are often reminded by reformers of every possible type, faults and vices enough; but in the main they are the vices and faults of youth—of youth somewhat impatiently and curiously approaching adolescence after an infancy of fifteen centuries. I desire in these pages briefly to consider this infancy and to indicate the main educational lines that have been followed in so vast a period of preparation. To do so will, I believe, be valuable, for, in the storm and stress of modern times, men are perhaps a little apt to neglect the principles of progress that have been wrung, at the cost of infinite tears, from nature in the past—principles that are the motives of history if we will but read it.

We know from the writings of Tertullian and Origen that it is now at least seventeen hundred years since christianity took root in Britain; while Zozomen and Eusebius reveal to us, in the fourth

century of our era, a complete and organized British church, holding the catholic faith, represented at the great church councils, and in intercourse with Palestine and Rome. This early church undoubtedly possessed and disseminated some measure of culture in the Isle, and when the first contact with the See of Rome came, that culture was certainly broadened, though from first to last during the Saxon period the spiritual control of Rome was specifically rejected. Augustine, the first Archbishop of Canterbury, came to Britain in 596 A. D., and to him in the year 601 A. D. Pope Gregory committed the charge of 'the Bishops of the British.' The church as reorganized by Augustine and his followers maintained the old independence, and when Theodore of Tarsus, a successor of Augustine in the See of Canterbury, deposed Wilfrid, Bishop of York, Pope Agatho was unable to compel either king or archbishop to restore him to his seat. This Theodore of Tarsus is one of the earliest names in English education. He and the Abbot Adrian, about the year 668 A. D., brought to England new means and methods of education. They made each of the greater monasteries an educational center, and it is certain that in this dark age Greek itself was taught to those who would learn. Indeed, the first important period of English culture was at hand. Bede tells us in his 'Ecclesiastical History' (Vol. IV., C. II.) that in the year 732 A. D. there were living in England disciples of Theodore and Adrian, who knew the Greek and Latin tongues as well as their own language. The use of Latin became indeed so usual that Bede speaks of it as 'the vernacular': 'The Creed and the Our Father I have myself translated into English for the benefit of those priests who are not familiar with the vernacular.' He himself taught in the monastery school at Jarrow, and wrote small treatises on the Trivium and Quadrivium for use in monastic schools. Alcuin was born into this first spring of learning in the year 735 A. D., and he boasts of the learned men and noble libraries of England. Charlemagne did all that he could to benefit by the scholarship that existed in our island, and in securing the services of Alcuin he initiated that earliest movement of Gallic culture which resulted in the creation later of the University of Paris. The first English period died away all too soon. "The sloth of the priesthood, the unrest of the land, the red ruin of the Dane, killed it south to north, and when Alfred came all that was left were some stray vestiges of scholarship in far Northumbria." The age was dark indeed, and despite the remarkable efforts made by the church of Rome in the ninth century for the extension of learning and the founding of schools,* little could be done. Alfred did what could be done. He

* See the Canon *de scholis reparandis pro studio literarum* promulgated at the Concilium Romanum in 826 A. D., in the time of Pope Eugenius II. This canon appears to be little known to educationists. It should be read in connec-

founded and endowed with an eighth of his income a school mainly for the children of his nobility. Possibly, however, even serfs could attend this school. He also secured the freedom from tribute of the Saxon school in Rome. From this time forward we find that steady educational progress can be noted. King Ethelstan, by a law of 926 A. D., bestowed certain special benefits on learned clergy and thus founded the doctrine of 'Privilege of Clergy'—the right of a person (lay or clerical), who could read, to special rights in relation to the criminal law. This privilege in the middle ages certainly aided the spread of learning and though, when abolished in England in 1826, it had long outgrown all meaning and even all harmfulness, its importance as an educational factor must not be forgotten.*

The development of education from the ninth century onwards was in the hands of the national church for many generations. It was the practice, both in England and in France, from the end of the eighth century, for the mass-priests to hold at their houses schools for young children and, at any rate from the tenth century, it was usual for parents to pay school fees. The Church of England by thus creating an elaborate educational system rapidly established a new claim to the possession of a national character. With the coming of the Normans in 1066 and the sudden increase of papal influence, we might expect to find, as we do find, the bishops speaking on educational questions in an authoritative manner. Rome realized the importance of exercising control over schools, and of fostering their increase, and she developed this policy in spite of the stern anti-Roman position eventually exhibited by William I. We must note here two canons on the question of education which, though promulgated at national synods sitting at Westminster, really emanated from Rome. Canon XVII. of 1138 A. D. ordained that schoolmasters should not, under penalty of ecclesiastical punishment, 'hire out' their schools. This canon made for efficiency. The man who took the fees must teach the school. Canon VIII. of the year 1200 ordained that nothing should be exacted by the church from schoolmasters in return for the license to teach. This canon shows how widespread was church control over education in the opening of the thirteenth century. This power of granting licenses to teach created a valuable and valued monopoly, and local records (such as the records of Beverley Minster) prove that many a stern fight took place between licensed and unlicensed schoolmasters for the lucrative right of instructing youth, and that on occasions the secular and spiritual courts came into col-

tion with decrees of the third Council of Lateran (1179 A. D.), the fourth Council of Lateran (1215 A. D.) and the Council of Vienne (1311 A. D.).

*I believe that benefit of clergy still nominally exists in some states of the Union.

lision on the subject. The crown, moreover, as in the Ferendon schools case, decided in 1344, absolutely declined to admit ecclesiastical patronage over the grammar schools of England. From about this same date the absolutism of the church over education was threatened in various directions.

The 'Black-Death' of 1348–9 had the result of driving foreign priests from the land. After the terrible ravages of the dread pestilence had been smoothed away by the hand of time, we find that one of the lasting economic results was the fact that priests of English birth and speech served the churches and schools. We know this from contemporary documents. John de Trevisa tells us that immediately after the 'Black Death' John Cornwaile, master of grammar, 'chaunged the lore in gramer scole and construccioun of Frensche in to Englische'; and by the year 1385 'in alle the gramere scoles of Engelond, children leueth Frensche and construeth and lerneth an Englische.' The influence of Rome was diminished by the growth of a purely national English priesthood. At this very time the Lollard movement dealt a new blow at papal power. John Wyclif entirely repudiated Roman Catholicism, and his ideas rapidly permeated the country. Many Lollard schools were founded, while great and successful efforts were made by Wyclif's followers to protestantize the existing grammar and parochial schools. The revolt was so effective that by statute in 1401 and by the constitutions of Archbishop Clarendon in 1408, Lollard schools and Lollard schoolmasters were suppressed with violence, and for the space of some fifty years were apparently exterminated. In the meantime the Commons, possibly through fear of Rome or of Lollardy, or both, determined if possible to stop the spread of education among the unfree classes. The Articles of Clarendon more than two centuries before had forbidden villeins to become clerks without the permission of their lord and special manorial customs to the same effect were not unusual. The Commons determined to strengthen if possible these old feudal customs—originally designed to preserve for the lord of the manor the labor of his hind—and in 1391 petitioned King Richard II. to ordain and command that henceforward no neif or villein should send his children to the schools for the purpose of enabling them to alter their social status by the acquisition of 'clergy.' Such a retrograde movement was impossible. Even in the twelfth century the serf had been able to struggle by means of education into a higher class,* and it was impossible now to close the door. The king, therefore, and boldly, rejected the petition, and in a few years the first statute of education, setting forth the right of man to education, became law. This act, passed in 1406 (7. Hen. IV. c. 17), declared that 'every man or woman, of what state or con-

* See the *de nugis curialium* (Distinc. 1, Cap. X.), by Walter Map (fl. 1180 A. D.).

dition that he be, shall be free to set their son or daughter to take learning at any school that pleaseth them within the realm.' This great step was reached just five hundred years ago. The universal right of all, bond or free, to education was placed on a firm and unalterable basis. Until that was done it would have been hopeless for the 'New Learning,' for the Renaissance, to take root in England. Great movements take hold, not of individuals but of nations, and unless this nation had been free and fit to learn it never could have received the new life of the spiritual movement, which, beginning with the work of Wyclif, concluded with the ironies of the political reformation under Henry VIII. The tremendous though futile efforts made by Robert Grossteste, Bishop of Lincoln, Roger Bacon, and their school to introduce the awakening culture of the thirteenth century into England proved that the work was impossible till England had become once more a free nation, speaking its own tongue, and proud of its own personality. The end of the fourteenth and the opening of the fifteenth century show us an England where these conditions, despite the growing power of the Papacy, were fulfilled. The power of the Pope in England was, despite its total illegality, immense. It was tolerated as a balancing force to political Lollardy, on the one hand, and a turbulent baronage on the other. The country paid a heavy price, in illegal taxation and the farming of benefices in the interests of Rome, for the political benefits derived from the tacit suspension of the anti-papal legislation on the statute-book. But the great power of the papacy during the fifteenth century was exercised in regard to education on the whole, to good effect. During that century the whole social order was changing. The feudal system was in its last stage, and under the stress of the Wars of the Roses the entire machinery of tenures was falling to pieces. The church during this period not only kept learning alive, but developed the grammar schools and made them effective feeders for the universities, drawing upon every class of society for the supply of scholars. It is true that the temporary suppression of the Lollard movement involved the closing of many schools, but it is evident that at the very period when these schools were attacked a larger policy was in the air. I have referred to the statute of 1406 which gave the right of education to all. The famous Gloucester Grammar School Case decided further (in 1410) that at common law every man who was able had the right to teach, and this fact undoubtedly bore fruit. Throughout the century competition among schoolmasters was keen in all the great centers of population, and there can be no manner of doubt that during the fifteenth century, before the introduction of printing, educational activity was preparing the way among all classes for the introduction of the 'New Learning' and the final rejection of papal interference in spiritual affairs.

When we regard the great movement known as the Reformation apart from the local incidents that appear to have precipitated it, we seem to see, in the present connection at any rate, the working of long ripening issues. The crown in the fifteenth century had been glad enough to play off Rome against a rebellious and heretical commonalty and a dangerous baronage. The opening of the sixteenth century presented a new scene of action, from which the feudal barons had disappeared. The commonalty and the king had now one thing in common: the old-standing hatred of papal interference and foreign taxation; while the moving force of the new learning was urging both king and people, unconsciously enough perhaps, towards the same end. The Renaissance, the lessons of history, and the hope of gain, all combined to make men see in a free and purified church that vision of national liberty and national isolation which had always been the ideal of English statesmen from Alfred onwards. So the Reformation came, affirming, only in more downright fashion, the policy laid down by Edward III. in the famous statute of Provisors of Benefices. The independence of the church of England indeed had been asserted over and over again from British times to Magna Charta, from Magna Charta down to the Reformation-Parliament, which, in the seven years from 1529 to 1536, finally did away with *de facto* papal supremacy. The notable fact of the Reformation legislation for us is that it finally broke the bond that Rome in the teeth of history and the law had bound round England. The separation from Rome played a notable part in the history of English education. The first result was an unhappy one. I have pointed out that in the century immediately preceding the Reformation the educational system in England was in many ways effective. In fact there was a primary class of schools that fed the grammar schools, while the grammar schools fed the universities. There are still extant a considerable number of both primary and secondary schools that were created during that period; but the number is but a small proportion of the noble medieval system. Henry VIII. and the ministers of his son Edward VI. in their haste to abolish all traces of Rome, to divert all papal taxation and to absorb the property of papal foundations, destroyed innumerable educational foundations. The chantry legislation alone would have compassed the practical destruction of the medieval system. It is, however, probable, nay, almost certain, that the Tudors had no desire in any way to injure national education. The advancement of learning was a thing dear to the hearts of Henry VIII., Edward VI., Mary I. and Elizabeth, but learning itself fell before the progress of a definite and destructive political policy. It was intended to recreate the destroyed foundations, but the funds nominally allocated for this purpose were diverted to other and less laudable uses.

The course of destruction, however, left the universities untouched—

indeed, their position was strengthened—and the desire for a national system of education grew with the development of the Reformation. Queen Elizabeth showed herself keenly interested in the task of creating the means that should bring the opportunities of learning within the grasp of her poorest subject. It is true that she insisted on the religious conformity of schoolmasters to the established church. To so insist was part of her conception of national unity; but this, at that date, was in no way inconsistent with an enlightened educational policy. Shortly after her accession she published special injunctions on the subject of education, while the bishops closely enquired into the character and quality of the teaching in their dioceses. Parliament moreover specially excepted all educational foundations from annexation on religious grounds, and also by the statute of apprentices of 1562 exempted 'a student or scolar in any of the Universitees, or in any Scoole' from the strict provisions of that act. Moreover, commissioners for charitable uses were appointed—a commission that still occasionally sat in the nineteenth century—who enquired into the abuses of educational foundations. A statute of 1588, which is still in force, attacked with increased vigor the dire corruption of these foundations. The act aimed alike at the universities and the schools. All educational foundations were, moreover, relieved from the burden of subsidies and other taxation. Nor was this all. The queen in 1571 incorporated by statute the Universities of Oxford and Cambridge in order to secure 'the mayntenannce of good and Godly literature, and the vertuouse Education of Youth within either of the same Universities.' It is interesting to note that this quotation from the preamble to the act uses, so far as can be ascertained, the word 'education' for the first time in its modern sense. We may say then that the great queen removed, in so far as in her lay, all artificial drawbacks to education; she opened up all educational endowments to the fittest scholars, and she gave a new and as yet unexhausted impetus to the university system, while she inspired both church and state with a new interest in educational matters.

After the death of Elizabeth, we find that the subject of education was doomed, in view of new political problems and in spite of the personal interest that James I. and probably Charles I. took in letters, to some neglect. Yet Parliament even in the stern days of 'the Great Rebellion' had time to think of education, for we find that Cromwell passed in 1649 a measure for education in Wales as well as a general act that diverted to national education tithe-rent charges of the value of £20,000 a year, and directed that if the annual sum fell below that amount it should be supplemented out of the national exchequer. We thus find in England as early as 1649 provision for parliamentary grants in aid

of national education. Local rates in aid of education existed in rare and sporadic cases, perhaps a century earlier than this; while it is interesting to note that in the colony of Massachusetts Bay as early as October 25, 1644, the general court granted a voluntary rate for the maintenance of poor scholars at Harvard College, and the Connecticut code of 1650 dealt with the whole question of rate-aided education. It is also well to remember that while this beginning of state and rate aid had almost died away in England before the beginning of the eighteenth century, yet the English crown in 1695 confirmed a New England statute creating a system of rate-aided education. The idea, however, soon vanished as completely in the American colonies as it did in the mother country. The restoration of Charles II. in 1660 sounded indeed the death note of the commonwealth conception of national education. It achieved as well an even more lamentable result, for it reduced the great Elizabethan system to a state of coma. Elizabeth, we have seen, insisted on religious conformity, but she did not allow this to interfere with her educational policy. The Act of Uniformity of 1662 and the Five Mile Act of 1665 seem to us to have been literally designed for the extinction of education. These acts involved such a peering into the lives of schoolmasters, such a course of inquisitorial folly, that the position became intolerable. Men would not become schoolmasters, and practically all secondary and (apart from a certain new movement to be referred to immediately) primary education ceased to exist. Education has no meaning when none but political and religious hypocrites are allowed to teach. The campaign against dissent and Roman catholicism may possibly be defended on political grounds, but, from the point of view of national education, the result was lamentable. For the third time national education had been destroyed; it seemed hopeless to try and evolve a fourth system.

That fourth system, incorporating much of the wrecked materials of the old systems, is receiving its coping-stone to-day. We must, therefore, briefly trace its growth. The Uniformity legislation that followed the Restoration was so severe in character that a reaction or a revolt from its operation was inevitable. The decisions of the courts of justice were the first sign of this reaction. The courts held that a schoolmaster, if he was a nominee of the *founder* or of the lay-patron of a school, could not be ejected from the school for teaching without the bishop's license (*Bates's case,* 1670); while it was decided in *Cox's case* in 1700 that there was not and never had been ecclesiastical control over any schools save grammar schools; that the church, in fact, had no control over elementary education. In *Douse's case,* decided in 1701, it was held that it was not a civil offence to keep an elementary school without the bishop's license. Hence the elementary school could escape the inquisition of the bishop whether imposed by statute or

ecclesiastical law. An act of 1714 exempted elementary schools from the penalties of the conformity legislation, and so such schools could, if they would, multiply. The opportunity for a great movement was at hand: the question for England, perhaps the question for civilization, was, would it be seized? To attempt to deal in any detail with the manner in which this opportunity, emerging so obscurely among the bitter political conflicts of the time, was seized, is beyond the scope of a review article,* but I may indicate some broad aspects of the movement.

First, we must remember that the modern system, though it includes now all the endowed educational foundations that had fallen on to evil days at the end of the seventeenth century, did not in any sense spring from those old foundations. It was not till the middle of the nineteenth century that the abuses in these foundations were remedied. "Whoever will examine," said Lord Kenyon in 1795, "the state of the grammar schools in different parts of this kingdom will see to what a lamentable condition most of them are reduced. * * * empty walls without scholars, and everything neglected but the receipt of the salaries and emoluments." The state of the Court of Chancery was such that it would have ruined any individual as well as the endowment to have brought almost any specific case before the courts. These foundations lay dormant till better days—till the days of the grammar school act of 1840 and the endowed schools act of 1869. It may be stated generally that it was not until after 1870 that the ancient grammar schools and endowed schools—the numerous secondary schools of the country which are now proving of such vast importance in coordination with the state-aided primary system—became in any sense efficient. Yet we have to look to a certain class of endowed schools for one source of the modern elementary system. In England and Wales there were in 1842 some 3,000 endowed schools and of these more than 1,000 were founded between the years 1660 and 1730. This extraordinary movement, which has left so vast a result, is certainly difficult to understand. About the year 1660 church and state had practically suppressed endowed education, and yet in the face of that suppression a huge endowment movement arose. One explanation is certainly *Bates's case,* which decided in 1670 that a schoolmaster presented by the founder of a school or by a lay patron could not be ejected from his office by reason of his not holding the bishop's license. This case was a direct incentive to all dissenters, and to all who hated the Erastianity of the period, to found schools where children could be safely educated. This appears to be a reasonable explanation of a movement which was as remarkable as it has been unnoticed by historians. This explanation finds support in the

* I have dealt with it at some length in my volume on 'State Intervention in English Education,' published last year by the Cambridge University Press.

fact that the charity schools movement—largely supported by dissenters—to some extent synchronized in its early rapid development with this school endowment movement. The Act of Uniformity (1662) pressed with great severity on the dissenting schoolmasters, and, in order to give them relief, Dean (afterwards Archbishop) Tillotson and Richard Baxter (the distinguished writer and dissenter) combined in 1674 to draft a 'Healing Act' that should make the spread of elementary education possible. The bishops would not accept the compromise, but it is probable that it had some indirect effect, for the church made few attempts to interfere with dissenting schools, though they were often attended by church children.

The earliest 'voluntary' schools were started in Wales in 1672 by Thomas Gouge, a clergyman of the established church, who had been ejected from his living on Bartholomew's Day, 1662, under the provisions of the act of Uniformity. The bishops sanctioned his Welsh schools, and in 1674 a strong committee of churchmen and dissenters was formed in London to carry on the good work. In 1675 there were 1,850 children at school, of whom 538 were educated by Welsh voluntary subscriptions. John Strype, writing before 1720, connects this work with the charity school system, started in 1698 by the Society for Promoting Christian Knowledge. This latter movement was immensely successful and spread all over the country. In 1729 there were no less than 1,658 schools, containing 34,000 children. I have elsewhere estimated that, allowing a considerable margin for overlapping between the endowment movement and the charity school movement, there were over 2,500 schools of all classes founded in England and Wales between 1660 and 1730, that over one hundred schools received supplementary endowments and that 650 unattached educational charities were created. These schools supplied the poor with such education as was to be had in the eighteenth century—the education given was ineffective enough, but it was at any rate better than nothing. Special efforts were made in heathen Wales. Griffith Jones, a clergyman of the established church, in 1730 started 'circulating schools' in the towns, villages and wild country districts. The teachers stopped in each district for a few months only and then passed on to other centers. The Society for Promoting Christian Knowledge helped the movement, and large funds were supplied by a Mrs. Bevan, who carried on the schools after Griffith's death in 1761. At that date there had been 3,000 schools opened, in which 150,000 scholars had been taught. There were 10,000 children in the schools in 1760. In 1779 Mrs. Bevan died and bequeathed her large property to the carrying on of the work. Her estate was thrown into chancery and the schools were closed for thirty years. Such were the changes and chances of education in the eighteenth century. All higher education—apart from the work, often great, of individuals here and there, such as Isaac

Newton and certain university developments (such as the foundation of various chairs) destined to bear fruit in later days—was asleep, while primary education was poor indeed. It was, however, living and awake and so led on to the great revival of the nineteenth century.

Three new causes united with the new foundations and the charity schools to produce this revival. The first was the Sunday School system, tried by John Wesley in Savannah in 1737, but only introduced into England in 1763, made a national system by Robert Raikes, of Gloucester, in 1780 and brought to London about 1785, when the Sunday School Society was founded. In 1834 there were about 1,500,000 children with 160,000 voluntary teachers in the Sunday Schools of England and Wales. The secular work done by these schools was most valuable. In Manchester we find that in 1834 Sunday Schools were open for secular instruction for five and a half hours on Sunday and for two evenings in the week, and that the ages of the scholars varied from five to twenty-five years. Manchester in those days was still writhing under the scourge of universal child labor, and the Sunday Schools did work that secured the social salvation of thousands. In Mr. Benjamin Braidley's Manchester Sunday School there were 2,700 scholars, taught by 120 unsalaried teachers, all, save two or three, former scholars. The self-sacrifice to be found in the Manchester of those days perhaps more than balanced the sorrows involved in the policy of the Manchester school and David Ricardo. The second cause to which I have referred was the introduction of the monitorial system between 1798 and 1803, by Andrew Bell, a clergyman of the established church (who subsequently founded in 1811 the National School Society), and Joseph Lancaster, who received the close support of King George III., and from whose work sprang in 1814 the British and Foreign School Society. These two men worked with immense vigor at their task and quarreled with no less energy. Their quarrel for precedence as the discoverer of the monitorial system was taken up by the political parties of the day. The tories or church party supported the claims of Dr. Bell, while the whigs and dissenters rallied round Mr. Lancaster. The system was in itself a bad one. It was the parent of the modern pupil-teacher system and gave permanence to the lamentable practice of employing untrained teachers. We may, therefore, believe that the quarrel for precedence was unimportant. It had, however, two vast issues. It created the modern religious or denominational controversy which has had such a marked influence on the development of primary education in England, and it also brought education into modern politics.

The third cause to which I have referred above is this connection between education and politics, a relationship which has evolved the elaborate educational system that found its completion in the education act of 1902. The earliest legislation on the subject of national

elementary education in the modern sense was carried through Parliament in 1802—just a century before the great statute of last year. The factory act of 1802 was intended to deal with the health and morals of children employed in cotton and other mills and factories. The state of the children in these factories and mills was deplorable: ignorant beyond all imagination; housed under conditions subversive of all health, of all morality; working by methods that involved the stagnation of intelligence; these children presented a fearful problem and constituted a positive menace to the future of society. The act of 1802 was passed without discussion: it directed the mill rooms to be whitewashed twice a year and to be ventilated; it ordered an apprentice to have one suit of clothes a year and not to work more than twelve hours a day exclusive of meal times; it forbade work between nine at night and six in the morning; it provided that male and female apprentices should sleep in separate rooms and not more than two apprentices should sleep in one bed; it made medical attendance compulsory in case of infectious disease; it directed the mills to be inspected by visitors appointed by the justices and ordered the children to be taught the elements of knowledge and the principles of christianity. It is an awful picture; a picture for which the discovery of machinery and of the usefulness of children in machine work are responsible. This reformatory measure was petitioned against in the following year by both manufacturers and parents and it was never enforced. Many generations of little, seven-year-old slaves—the thought is heart-breaking—were to be worn away in the mills before, late in the century, effective relief came. Until 1878 children under nine years of age could be employed in silk mills. At the present time every child in the country—who is not specially exempt on the ground of adequate private teaching, sickness, inaccessibility of school, or other reasonable excuse—is compelled to attend school full time between the ages of five and at least twelve years (save in the case of children employed in agriculture when the child may be partially exempted at eleven). Moreover every local education authority may make by-laws compelling attendance up to the age of fourteen years. The child can, however, be employed during holidays or during hours when the school is not open; and this is a source of abuse. A child can not do his school work and school play and also be an up-hill down-dale errand boy. However, the change in the matter of child labor is remarkable since that year of grace 1802 and it may be admitted that some forms of employment in non-school hours are better than idleness with its concomitant evils.

From this time parliamentary interest in educational matters increased very rapidly. Mr. Whitbread's bill of 1807 provided for the establishment of schools and the appointment of schoolmasters by

the magistrates in every school-less district. All poor children were to be entitled to two years schooling between the ages of seven and fourteen years. The bill was mangled in the Commons and lost in the Lords. In 1816 a select committee was appointed to report on the education of the lower orders. In 1818 it reported on the condition of the country at large. 'The anxiety of the poor for education' was daily increasing, though the opportunities were very bad. The single-school (mostly church-school) districts showed, however, an increasing degree of liberality, and the religious views of the school were not pressed upon the children of parents holding other views, provided that the children were really taught such other views. This committee recommended the universal use of a conscience clause, the establishment of rate-supported, free parochial schools in very poor districts—the principle of the act of 1870—and, in rich districts, the making of grants to aid in the building of schools the maintenance of which would fall upon voluntary subscribers—the principle adopted by Parliament in 1833. Had both these suggestions been accepted in 1818, educational progress in the nineteenth century would have been far more rapid.

In 1820 Mr. Brougham introduced his first education bill. In his speech he fully recognized the labors of the clergy on behalf of education, and he noted the great improvement of the position since 1803. Then only one in every 21 persons in the population was at school, while in 1820 it was one in every 16 persons. This meant, however, that still one fifth of the population was without the means of education. Moreover, London was still 'the worst-educated part of Christendom.' The bill proposed the universal establishment of parochial schools with efficient teachers. Funds were to be found by local rates and by the diversion of old endowments. The religious teaching was to be undenominational. This bill was opposed both by the dissenters and the Roman Catholics, and was abandoned after the second reading.

Thirteen years now passed without legislative effort, but these years saw the growth of a great volume of public opinion. Mr. Brougham's pamphlet entitled ' Observations on the Education of the People,' published in 1825, ran through twenty editions in less than a year, and on all sides the importance of the problem received recognition. The year 1833 produced the first results of the educational renaissance. On Saturday, August 17, the House of Commons voted the sum of £20,000 in aid of private subscriptions for the erection of school-houses. The new era of definite state intervention in the education of the people may be said to have opened with this vote. From that date to this an ever-increasing annual vote for education has dignified and justified the statute book.*

* Over £10,000,000 was voted by Parliament for Elementary Education in England and Wales for the year 1902–3.

(*To be continued.*)

# DISCUSSION AND CORRESPONDENCE.

## THE QUESTION OF RACIAL DECLINE.

To the Editor: I have read in your June issue the article entitled 'Race Decline' by George J. Engelmann, M.D., of Boston. The writer states 'The American population is not holding its own, it is not reproducing itself,' etc., and quotes statistics of college classes and of Massachusetts to prove it. When a young man thirty years ago I heard the same story, and people predicted that the American people of native stock would be extinct in a few generations. The census of 1900 flatly contradicts the gentleman's statements. It shows that the rate of natural increase is not exceeded by any nation on the face of the globe. What has doubled the population (white) of the states in the south since 1870? There is but little immigration to that section. Also what causes the great increase of population in states like Indiana where the foreign born are decreasing?

The fact is that the native population is increasing very rapidly and is not dying out, not even in Massachusetts. We hear a great deal about the prolific French Canadians and their great natural increase. It may astonish some people that the native Americans are increasing just as rapidly and in the south much more so. I will quote a few statistics taken from the recent census.*

| | |
|---|---|
| Native born white native parentage | 41,053,917 |
| Under 20 years of age | 19,556,558 |
| Percentage under 20 | 47.6% |

* Vol. 2—Population, part 2, page 2, Table 1.

In the province of Quebec (French Canada) the 1901 census shows that 49 per cent. of the population were under twenty years of age, or a little more than 1 per cent. more than the native Americans. If we omit those under five years of age the percentages will be as follows:

| | |
|---|---|
| Native American from 5 to 19 inclusive | 34.3% |
| French Canadians from 5 to 19 inclusive | 34.6% |

This indicates a greater death rate among the French Canadians under five years of age. Now for figures for typical native states I take Indiana in the north, and North Carolina in the south. In the former the foreign-born are but 5½ per cent. of the population and in the latter less than half of 1 per cent.

| Indiana. | |
|---|---|
| Under 20 years of age | 46.3% |
| From 5 to 19 inclusive | 34 % |
| **North Carolina.** | |
| Under 20 years of age | 51.7% |
| From 5 to 19 inclusive | 37 % |

Notice how much larger the percentage of children in North Carolina is than in French Canada. This is typical of all the southern states. Among the mountaineers the percentage of children even exceeds this, and a comparison of the number of children among these people and the French Canadians would make the latter look like a decadent race. It is true that in Massachusetts and some of the adjoining states the foreign element increases in the natural way more rapidly than the native, but this does not hold good as to the whole country.

But the showing made by Massachusetts is not as bad as indicated by Dr. Engelmann. I quote from Vol. 3 of

the U. S. Census Vital Statistics, Part 1, page 356, for the census year ending May 31, 1900. This does not indicate that the native is dying out in Massachusetts.

Massachusetts: Births and Deaths.

| | | |
|---|---|---|
| Both parents native, births.... | | 21,343 |
| Both parents native, deaths (all ages) ..... | | 15,357 |
| Natural increase ..... | | 5,986 |
| One or both parents foreign ..... | 44,252 | |
| Foreign born..... | 624 | 44,876 |
| Natives, one or both parents foreign, deaths (all ages) ..... | 16,194 | |
| Foreign born ..... | 13,645 | 29,839 |
| Natural increase..... | | 15,037 |

While the above shows a very healthy increase among the natives of Massachusetts it also indicates a larger increase among the foreign element. But in this connection it must not be forgotten that a very large proportion of those included in the foreign element are of the same stock as the natives. Thus in Massachusetts there are nearly a half million English, Scotch, Welsh and English Canadians, both foreign and native born. I think the foregoing shows pretty conclusively that the natives are not dying out and that all opinions to the contrary are based on a false foundation.

C. E. SMITH.

BROOKLYN, N. Y.

[WE publish Mr. Smith's letter as the question is of such importance that it should be discussed from all sides. It ought to be said, however, that statisticians hesitate to draw conclusions as to racial increase from the figures of the census. When the native population increases from one census to another, this is partly and may be entirely due to the children of foreign parents who are counted as natives. When Mr. Smith gives figures showing that in Massachusetts the births when both parents are natives exceed the deaths when both parents are natives, it should be noted that the births come from a considerably larger group than the deaths. The native children of foreign parents are not counted among the deaths, but their children are counted among the births. It is also true that after a period when the native population has increased (perhaps only by children of foreign parents) there would be an excess of births. Mr. Kuczynski in his careful analysis of the fecundity of the native and foreign-born population in Massachusetts (*Quarterly Journal of Economics*, November, 1901, and February, 1902) states that in Berlin, where proper statistics are collected such as do not exist in this country, the birth rate is not sufficient to maintain the population. But in Berlin there was an annual birth rate of 10 for every 100 married women in child-bearing age, whereas it was only 6.3 in the native population of Massachusetts.

It seems also fair to our readers to state that we do not accept the conclusions of Dr. Engelmann published in the last number of the MONTHLY. In an article such as Professor Fleming's on 'Wireless Telegraphy,' we have simply to learn what the leading authority on the subject teaches us. When we leave the exact sciences, and especially when we enter the field of applied sociology, we have our science to make. The fact that sociology is now in about the condition of the physics of three hundred years ago does not detract from its interest, but rather adds to the possibilities of progress. Readers should, however, remember that while a physicist can usually speak for the science of physics, a sociologist can usually only speak for himself. The fact that the editor of this journal does not agree with Dr. Engelmann in regard to the interpretation of statistics does not necessarily mean that Dr. Engelmann is mistaken, but only that the subjects are not yet in the field of exact science.

Dr. Engelmann claims that an older age at marriage does not mean a smaller family, that the marriage rate of the college graduate is higher and the size of the surviving family larger than in the population at large, and that the decreasing size of family is entirely voluntary. We think that he has established none of these conclusions. Adequate statistics may not be at hand correlating the size of family with the age of marriage, but it seems almost certain that there is an inverse correlation, those who marry later having fewer children. This would hold especially for women—and older men are likely to marry older women—and for men who remarry. It is also of course true that earlier marriages produce a more rapid sequence of generations and a larger population.

Dr. Engelmann gives 2.1 as the size of family of graduates more than twenty years out of college and 1.9 as the size of family of the native-born in Massachusetts, and tells us that the college graduate does more towards reproducing the population than does the native American of other class. He appears to be in serious error in his statistics. A certain loyal Princeton graduate discovered that his class of '76 had 2.7 surviving children for each married graduate. Whether this case is typical or not we do not know, but Dr. Engelmann gives it the same weight in his average as the 1.86 obtained from 1,401 Harvard graduates. The families of Princeton and Yale graduates and of many Harvard graduates coming from a region having higher fertility can not be compared with the decadent native population of Massachusetts, nor can college graduates in part of foreign origin be compared with the exclusively native population. Dr. Engelmann compares the native surviving Massachusetts family of 1.9 with that of college graduates of more than twenty years' standing. The native population includes girls of fourteen and women just married. The average number of living children of native women of Massachusetts between the ages of forty and forty-nine was 2.13. With this family and a marriage rate of 79 per cent. the population is rapidly decreasing. Harvard graduates, with a marriage rate of 71.4 and a family of 1.86 surviving for a time are destined to even more rapid extermination. The Harvard graduate of New England stock is doubtless still more infertile, but we have no exact information in regard to this, nor as to whether or not the college graduate is more infertile than the race and class from which he comes. EDITOR.]

## SCIENTIFIC LITERATURE.

### *PSYCHOLOGY.*

THERE has just been published a group of psychological books which could scarcely have been produced elsewhere. In both volume and value of work, American psychologists appear to hold their own with Germany and to surpass Great Britain or France. The books to which we especially refer are 'Experimental Psychology and Culture,' by Professor Stratton, of the University of California; 'Outline of Psychology,' by Professor Royce, of Harvard University; 'Genetic Psychology for Teachers,' by Dr. Judd, of Yale University, and 'Why the Mind Has a Body,' by Professor Strong, of Columbia University.* If we go back a couple of years, there may be added 'Talks to Teachers,' by Professor James, of Harvard University; 'Psychology and Life,' by Professor Münsterberg, of Harvard University; 'Fact and Fable in Psychology,' by Professor Jastrow, of the University of Wisconsin; 'Introduction to Psychology,' by Professor Calkins, of Wellesley College; 'Experimental Psychology,' by Professor Titchener, of Cornell University, and 'Analytical Psychology,' by Professor Witmer, of the University of Pennsylvania. We have in addition the monumental 'Dictionary of Psychology,' edited by Professor Baldwin, of Princeton University, the third and last volume of which has just been published, and various works limited to a special field, such as Professor James's 'Varieties of Religious Experience' and 'Aristotle's Psychology,' by Professor Hammond, of Cornell University. The books can not be said to represent a school of psychology, but they show certain rather definite tendencies. They are scientific, being based on the results of recent experimental research, and yet they tend to maintain an intimate connection with philosophy. The relations to education are strongly emphasized. The human interest and literary style are noticeable, being scarcely equaled by similar works in other sciences.

This is not the place for critical reviews, but a few words may be said about the contents of the books that have just been issued. Professor Strong's work is somewhat technical in character, but is scarcely beyond the comprehension of the untrained reader. It discusses the relations of mind and body, defending a parallelism that gives room for the efficiency of mind and an idealism that makes consciousness the reality that appears as the brain-process. The books by Professor Royce and Dr. Judd both appear in series for teachers, but they differ widely in their contents and methods. The former is a general treatise on psychology, in which the phenomena are classed in a new way under the heads of sensitiveness, docility and initiative; the latter contains chiefly concrete facts of direct use to teachers. Professor Stratton's book is a well-informed and well-written account of some of the results of experimental psychology treated in relation to wider interests. The difficulty in recommending a book on psychology for students of other sciences or for general readers is not now in the lack of books, but in their number and excellence. .

*The books are published by The Macmillan Company, except Professor Judd's which is one of the International Education Series of the Appletons.

# THE PROGRESS OF SCIENCE.

## *LORD KELVIN ON 'CREATIVE PURPOSE.'*

THERE has been in progress in the columns of the London *Times* a correspondence on certain serious topics that has aspects both amusing and pathetic. Lord Kelvin, in moving a vote of thanks at the close of a lecture before the Christian Association of University College, London, said that "science positively confirmed creative power. . . . Modern biologists were coming to a firm acceptance of something, and that was a vital principle. . . . They were absolutely forced by science to admit and to believe with absolute confidence in a directive power." Lord Kelvin subsequently explained that a fortuitous concourse of atoms would account for the formation of a crystal, but that creative power is necessary for the growth of a sprig of moss. Sir William Thistleton-Dyer, director of the Kew Botanical Gardens, calls Lord Kelvin sharply to account, saying that 'for dogmatic utterance on biological questions there is no reason to suppose that he is better equipped than any person of average intelligence.' Sir William is, however, ready to enter the field of physics, and tells Lord Kelvin that his ether is 'a mere mathematical figment.' Sir John Burdon-Sanderson intervenes to express regret that "A most distinguished British botanist has thought it necessary to 'cross swords' with the most distinguished of British physicists with reference to a question on which it is desirable that all men of science should be in accord," and to disclaim on the part of his own science, physiology, the opinion that Lord Kelvin is not competent, when von Helmholtz has spoken of his 'surprising acuteness, clearness and versatility.' But Sir John immediately proceeds to state that physiologists do not believe in a vital principle, that the processes of animal and plant life are governed by the natural laws which have been established for the inorganic world. Mental processes and organic evolution can not, however, be directly measured or observed. In spite of the desirability of accord and of Lord Kelvin's great competence, he is mistaken as regards Sir John's science, though psychology and organic evolution may very well be outside the range of exact science. Sir Oliver Lodge, the eminent physicist, does not like the phrase 'creative power,' but believes that the formation of an animal or plant requires in addition to the laws of mechanics 'the presence of a guiding principle or life-germ.' He also regards 'telepathy' as a recently discovered fact. Professor Ray Lankaster, director of the British Museum of Natural History, thinks that an injustice would be done both to Lord Kelvin and to his critics unless he points out the significant features of the matter. Professor Karl Pearson, Mr. W. H. Mallock and others have joined in the discussion, and it is the theme of editorial articles in the *Times* and *The Spectator*, both of which are orthodox and dogmatic.

It is a fact of some interest that British physicists have been inclined to religious orthodoxy — Faraday, Maxwell, Stokes and Kelvin may be mentioned. Sir Oliver Lodge believes in telepathy and Sir William Crookes in ghosts. The physical sciences have outlived their conflict with current theology, whereas in the past half century biology has had to bear the

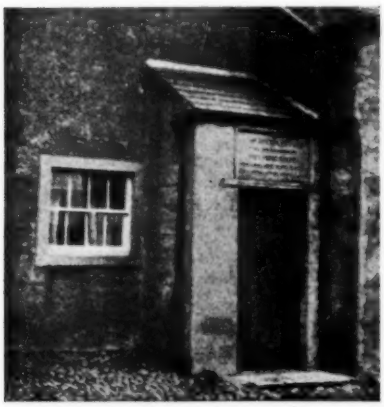
brunt. The physicists hold that their realm is governed by their laws, but that the biological kingdom is a theocracy. It appears that there is as much or as little evidence for teleology in an earth suited for life as in its inhabitants, as much or as little evidence for creative purpose in a crystal or a solar system as in a sprig of moss or a man. But perhaps such a statement is in continuation of the dogmatism, to which attention has been called.

### *CELEBRATIONS IN HONOR OF DALTON AND LIEBIG.*

THERE have recently been celebrated the centenary of Dalton's discovery of the atomic theory and the hundredth anniversary of Liebig's birth. The ceremonies in honor of Dalton were at Manchester, a city which gave birth to two of the great scientific advances of the last century, the atomic theory and Joule's work on the mechanical equivalent of heat. Manchester has an ancient and active Literary and Philosophical Society, which invited Professor F. W. Clarke of the U. S. Geological Survey, chairman of the International Commission on Atomic Weights, to give its Wilde lecture. He reviewed the history of the atomic theory from its first conception among the Greeks to the present day and outlined the work still needed. Professor J. H. van't Hoff, of Berlin, was presented with an address by the Owens College Chemical Society, and laid the cornerstone of the extension of the chemical laboratory. The Wilde medal of the Literary and Philosophical So-

ciety was presented to Professor Clarke, and he and Professor van't Hoff received the degree of Doctor of Science from Victoria University.

John Dalton was born in 1766 of Quaker parentage. He began to teach school at the age of twelve, and supported himself through life by teaching, and later by making analyses for local manufacturers, being thus one of the earliest professional chemists. From 1793 until his death in 1844 he lived quietly at Manchester, unmarried and entering but little into society. He was made secretary of the Literary and



MEMORIAL TABLET OVER DOOR OF HOUSE IN WHICH JOHN DALTON WAS BORN.

From a photograph supplied to *Nature* by Mr. A. Humphreys. The inscription on the tablet reads: — "John Dalton, D.C.L., LL.D., the Discoverer of the Atomic Theory, was born here Sept. 6, 1766. Died at Manchester July 27, 1844."

Philosophical Society in 1800, was its president after 1817, and carried on his chemical work in the rooms of the society. He was a member of the Paris Academy before he was elected to the Royal Society, but finally received all the usual honors. Dalton once said:

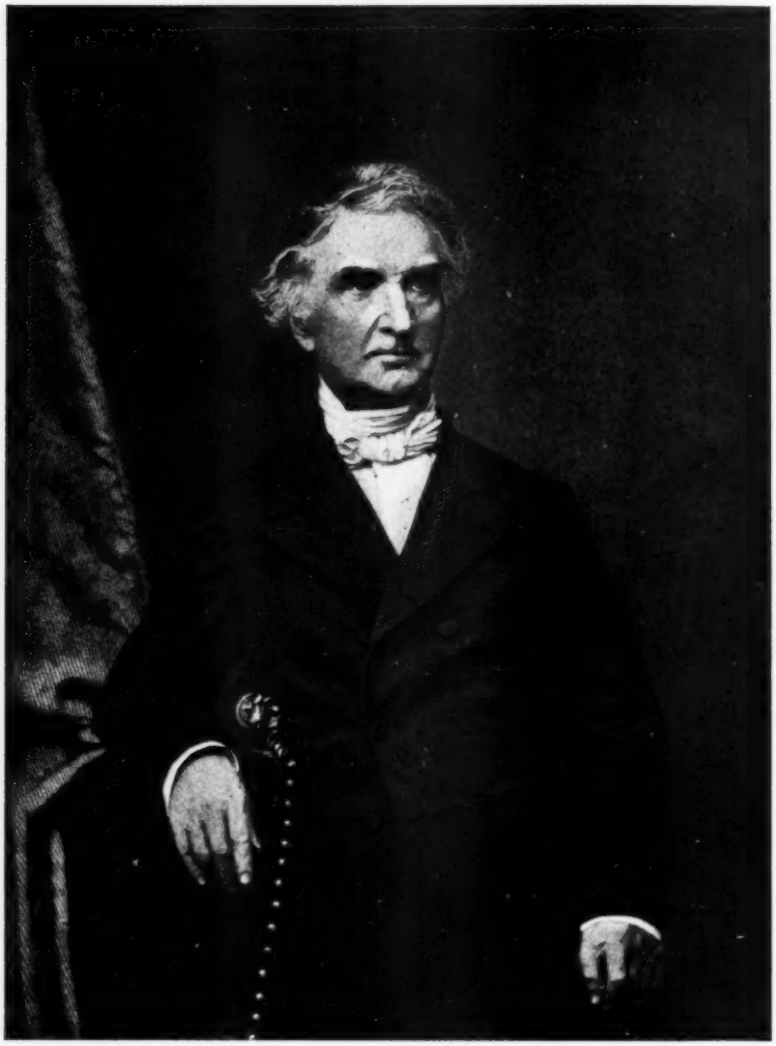
> With regard to myself, I shall only say, seeing so many gentlemen present who are pursuing their studies, that if I have succeeded better than many who surround me in the different walks of life, it has been chiefly — nay I may say almost solely — from unwearied assiduity. It is not so much from any superior genius that one man possesses over another, but more from attention to study and perseverance in the objects before them, that some men rise to greater eminence than others. This it is, in my opinion, that makes one man succeed better than another.

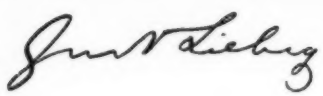
Yet his own life supports the theory of innate genius, for though he worked diligently to the end, his great discoveries were made while he was a young man. It is generally known that he discovered color-blindness, sometimes called Daltonism; he also did much work in meteorology, recording over 200,000 observations; he is said to have enunciated the law of the expansion of gases before Gay-Lussac; he carried on research in different departments of physics and chemistry. But of course his great discovery was the atomic theory, the centenary of which has just been celebrated. The theory, like most others, was of gradual development, but, as Dalton says in a letter to his brother in 1803, he had 'got into a track that has not been much trod before,' and this track has become the highway of modern chemistry.

Justus von Liebig was born on May 12 of the year in which Dalton formulated the atomic theory, and the hundredth anniversary of his death has been celebrated in Germany and here. In New York there was a meeting of chemists, which was addressed by President Remsen, of the Johns Hopkins University, whose laboratory has done much to carry forward the work in organic chemistry which Liebig founded; by Professor Brewer, of Yale University, one of Liebig's oldest pupils, who has continued his work on agricultural chemistry, and by Dr. Carl Duisberg, managing director of the Farbenfabriken of Elberfeld, who spoke of Liebig's influence on the chemical industries.

There will be found articles on Liebig in the third, ninth and twentieth volumes of this journal, the last being

an extremely interesting autobiography. Like many others who have attained eminence in science, Liebig did not profit much from the existing system of education; but as a boy he read all the books on chemistry in the order in which they stood on the shelves of the Court Library and made his own experiments. At the university things were not much more to his taste. He attended the lectures of Kastner, regarded as an eminent chemist, but capable of telling his students that 'the influence of the moon upon





the rain is clear for as soon as the moon is visible a thunderstorm ceases.' The science of the universities was under the domination of the 'speculative physics' of Hegel and Schelling, whose chemistry is fairly represented by such a quotation as "Water contains just the same as iron, but in absolute indifference as yonder in relative indifference, carbon and nitrogen, and thus all true polarity of the earth is reduced to an original south and north which are fixed in the magnet." What Liebig accomplished will be better appreciated if the deplorable state of science in the German universities is recalled.

Liebig was made professor of chemistry at Giessen at the age of twenty-one, and full professor two years later. He immediately proceeded to establish a laboratory for students, the prototype not only of chemical laboratories, but of the laboratory method in science. In 1852 he removed to Munich, where he died in 1873. Like many other men eminent in research, Liebig was a great teacher, an editor and a popularizer of science. He also combined the discovery of facts with the formulation of wide-reaching theories. Neither the facts nor the theories can be described here; it suffices to say that Liebig may properly be regarded as the founder of organic, physiological and agricultural chemistry.

### *THE AMERICAN MUSEUM OF NATURAL HISTORY.*

THE thirty-fourth annual report (that for 1902) of the American Museum of Natural History in New York City records the events of a prosperous year for the institution. During the year the membership increased materially, and the attendance on lectures was larger than ever before. Several scientific societies held their regular meetings in the building. In October, 1902, the International Congress of Americanists held its thirteenth annual session at the museum, and discussed subjects relating to 'The Native Races of America' and 'The History of the Early Contact between America and the Old World.'

In May 1902, upon the arrival of the news of the disaster in Martinique, Dr. Hovey, of the Geological Department, was detailed by the president to investigate the causes of the eruptions, and his work has placed the museum among the leading contributors to seismology.

The additions to the collections of mammals during the year numbered more than 2,000, secured largely through the museum collectors. The gift of the Peary Arctic Club of about one hundred mammals, collected by Commander Peary on his last Arctic expedition, is especially noteworthy. The museum is now the richest in the world in mammals from Arctic America. The donations from the New York Zoological Society and the Central Park Menagerie are of great value to the museum. The specimens of mammals obtained by the Andrew J. Stone Expedition in North British Columbia form the largest single collection that has ever been brought down from the north. In the Bahamas and Virginia material was collected for special bird groups for the museum. The vertebrate paleontological collections of the museum were enriched by expeditions maintained in the field, and the establishment of a fund by a member of the board of trustees for providing material to illustrate the origin and development of the horse produced immediate results of the highest importance. The Cope collections, the purchase of which was effected in the year, include fossil reptiles, amphibians and fishes, and the Pampean collection of fossil mammals from South America.

A number of archeological collections not before exhibited were installed, notably the valuable collections made in the southwest under grants furnished by the Messrs. Hyde. Through

the generosity of the Duke of Loubat and contributions made by the president of the museum and the Messrs. Hyde, the museum came into the possession of a very large amount of material illustrating the culture of ancient Mexico. Another exhibit worthy of note is that of a portion of the material obtained during the researches in the Delaware which have been carried on for more than twenty years. It seems to show that man was in the valley of the Delaware at the time that certain of the glacial deposits and those immediately following were made. The year was signalized by the conclusion of the explorations of Messrs. Bogoras and Jochelson, on account of the Jesup North Pacific Expedition, and their return to the museum with vast quantities of ethnological material. The expedition has covered the whole district from Columbia River in America westward to the Lena in Siberia, and it is already evident that the relationship between Asia and America is much closer than had hitherto been supposed. The Huntington California Expedition and the North American Research Expedition were continued in 1902, and much information gained in regard to certain of the native races of America. The east Asiatic work of the Expedition to China promises important scientific results. The Hyde Expedition carried on work in the southwest and in northern Mexico. The results of the work of the Mexican Expedition throw much light on the burial customs of the ancient Zapotecans, and the collections obtained add materially to the importance of the collection in the museum. Rare specimens of gold, copper and jadeite secured by the expedition, added to those already in the museum, make this part of the Mexican collection the best in any museum. From the Duke of Loubat the museum received a gem collection of great importance from the state of Oaxaca. Local explorations were carried on in the Shinnecock and Poosepatuck reservations on Long Island and Staten Island and at Shinnecock Hills.

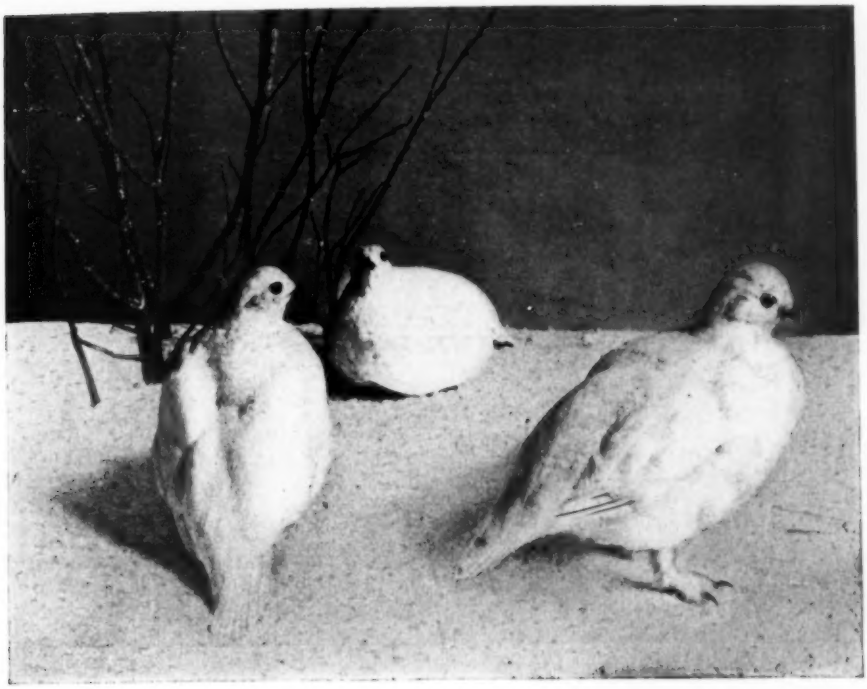
Several additions were made during the year to the gem collection, in the Department of Mineralogy, namely, five magnificent crusts of amethyst, a large yellow sapphire, two parti-colored sapphires, an immense star sapphire, and a curious archaic axe of agate, gifts of Mr. J. Pierpont Morgan. A splendid collection of gold and silver coins from the Philadelphia mint, the gift of Mr. Morgan, was placed in the gem room.

The Department of Invertebrate Zoology received an important accession in a collection of West Indian corals, actinians and alcyonarians collected in Jamaica. The New York Zoological Society and the Department of Parks were the principal donors of reptiles and batrachians.

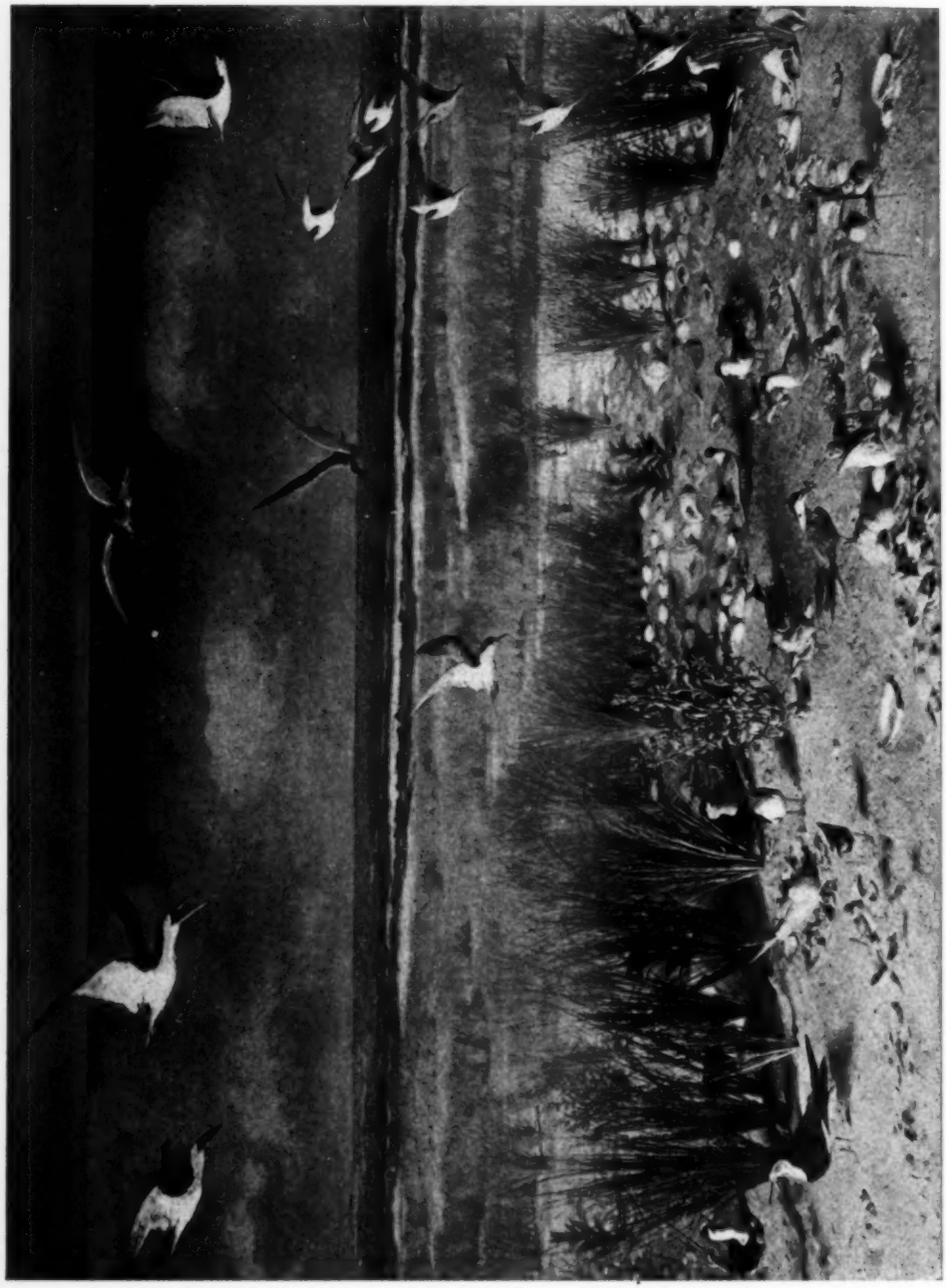
A section of one of the giant trees of California has been placed on exhibition and attracts considerable attention. The tree from which the section was cut was 1,341 years old; it was almost 30 feet in diameter at the base, and had reached a height of 300 feet. Cards indicating the discoveries in biology during the life of the tree have been attached to the mounted section.

In the Department of Entomology, the Hoffmann collection of butterflies was transferred to the new cases, and the Schauss collection of moths provisionally arranged. From the Black Mountains of North Carolina, 7,000 specimens were obtained for this department. The death of the Very Reverend Eugene A. Hoffmann, D.D., LL.D., removed a warm friend of the museum and a substantial support from the Department of Entomology.

The publications of the scientific results attending the investigations of the museum in various lines progressed during the year. Two numbers of the 'Memoirs' were issued, namely 'Kwa-



SCENES FROM THE PTARMIGAN GROUP



CENTRAL PORTION OF THE GROUP OF BEACH-BREEDING BIRDS OF COBB'S ISLAND

kiutl Texts' by Franz Boas and George Hunt, and 'The Night Chant, a Navaho Ceremony' by Washington Matthews. The amount of 'Bulletin' matter published is the largest in the history of the museum. Nine numbers of the *Museum Journal* and six 'guide leaflet' supplements were issued. The supplements describe collections in the museum, and their popularity is shown by the fact that several thousand were sold in the year at the entrances.

Several courses of lectures were offered under various auspices: To teachers, to members of the museum, and to the public (holiday course), under a grant from the state; to teachers, by the museum, in cooperation with the Audubon and Linnæan Societies; to the public, by the City Department of Education in cooperation with the museum.

In summing up his report, the president mentions several items that indicate the progress of the institution: "In concluding this my twenty-second report, I take pleasure in assuring the members of this board that the past year has been one of achievement. The increase in the annual appropriation, the growing popularity of the lectures, the large sums spent for laboratory research, the long list of publications, the opening of new exhibition halls, the appropriation by the city of $200,000 for a new power house, the receipt of large invoices of ethnological material from Siberia and China, the conclusion of negotiations leading to the purchase of the Cope collection, and the departure of several exploring expeditions, are only a few of the indices of activity at the museum, of the generosity of our friends, and of appreciation on the part of the city officers and the visiting public."

## *THE AMERICAN PHILOSOPHICAL SOCIETY.*

In the complex organization of American scientific societies, the American Philosophical Society 'held at Philadelphia for the promotion of useful knowledge' seems to be maintaining a place of its own. It was originally a national society founded on the model of the Royal Society, and the general meetings held last year and this show that it has to a certain extent maintained this position. Members from Philadelphia and the vicinity acted as hosts, and were able to welcome a considerable number of members from different parts of the country. Both the arrangements for social intercourse and the program compared very favorably with those of the meeting of the National Academy of Sciences, held at Washington in the same month. The meeting lasted for three days. In one of the evening sessions Dr. Edgar F. Smith, professor of chemistry in the University of Pennsylvania and president of the society, made an address on its origin and early history, drawing from original documents much interesting information in regard to the beginnings of science in America. At the same session Dr. D. C. Gilman, president of the Carnegie Institution, spoke of its work during the past year. After these addresses, which were given in the hall of the Historical Society of Pennsylvania, there was a reception, and on the following evening a dinner was given at the Hotel Bellevue, at which Professor W. B. Scott, of Princeton University, was toastmaster.

The meetings were held in the hall of the society, and a considerable number of interesting papers were presented. The American Philosophical Society includes philology and economics in its scope, and papers were presented by Professor March, of Lafayette College, on the development of the English alphabet; by Professor Haupt, of the Johns Hopkins University, on archeology and mineralogy; by Professor Jastrow, of the University of Pennsylvania, on the Hamites and Semites in the tenth chapter of Genesis, and by Professor Schelling, of the University of Pennsylvania, on the

supernatural in Elizabethan and Jacobean plays. We give these titles, as it is not usual to combine in one program papers in the natural and exact sciences and in the philological and historical sciences. The whole question of the relation of these two great groups of sciences to each other requires solution, and it is of interest to note that they were successfully combined at Philadelphia. The following new members were elected:

*Residents of the United States*—Edward E. Barnard, Sc.D., Williams Bay, Wis.; Carl Hazard Barus, Ph.D., Providence, R. I.; Franz Boas, Ph.D., New York; William W. Campbell, Sc.D,. Mt. Hamilton, Cal.; Eric Doolittle, Philadelphia; Basil Lanneau Gildersleeve, LL.D., Baltimore; Francis Barton Gummere, Ph.D., Haverford, Pa.; Arnold Hague, Washington, D. C.; George William Hill, LL.D., Nyack, N. Y.; William Henry Howell, Ph.D., Baltimore; Edward W. Morley, Ph.D., Cleveland; Harmon N. Morse, Ph.D., Baltimore; Edward Rhodes, Haverford, Pa.; Alfred Stengel, M.D., Philadelphia; William Trelease, Sc.D., St. Louis.

*Foreign Residents.*—Anton Dohrn, Naples; Edwin Ray Lankester, LL.D., F.R.S., London; Sir Henry E. Roscoe, F.R.S., D.C.L., London; Joseph John Thomson, D.Sc., F.R.S., Cambridge, Eng.; Hugo de Vries, Amsterdam.

Action was also taken looking to the adequate celebration of the two hundredth anniversary of the birth of Franklin, the founder of the organization. This was expressed in the following preamble and resolution which were unanimously adopted:

Inasmuch as the two hundredth anniversary of the birth of Benjamin Franklin occurs in January, 1906, it is proper that the American Philosophical Society, which owes its existence to his initiative and to which he gave many long years of faithful service, should take steps to commemorate the occasion in a manner befitting his eminent services to this society, to science and to the nation. Therefore be it

*Resolved*, That the president is authorized and directed to appoint a committee of such number as he shall deem proper to prepare a plan for the appropriate celebration of the bi-centennial of the birth of Franklin, and report the same to this society.

## *SCIENTIFIC ITEMS.*

PROFESSOR J. PETER LESLEY, the eminent geologist, died at Milton, Mass., on June 1, aged eighty-three years.

THE freedom of the city of Rome has been conferred on Mr. G. Marconi. —The German Chemical Society has conferred its gold Hofmann medals on Professor Henri Moissan and Sir William Ramsay.

DR. A. C. ABBOTT, professor of hygiene at the University of Pennsylvania, has been appointed chief of the Bureau of Health at Philadelphia. —James Harkness, A.M., since 1888 professor of mathematics at Bryn Mawr College, has been appointed by the board of governors Redpath Professor of Mathematics at McGill University.—Dr. W J McGee has been appointed chairman of the committee of the International Geographical Congress of 1904, succeeding General A. W. Greely, who has resigned owing to ill health and the pressure of official duties.—Dr. A. Graham Bell has resigned the presidency of the National Geographic Society.

AT the meeting of the board of trustees of the Leland Stanford Junior University held on June 1, Mrs. Leland Stanford resigned and surrendered all the powers and duties vested in her by the terms of the grant founding the university, under which she had complete control. That control is now vested in the board. Mrs. Stanford will be elected a trustee, and will be elected president.